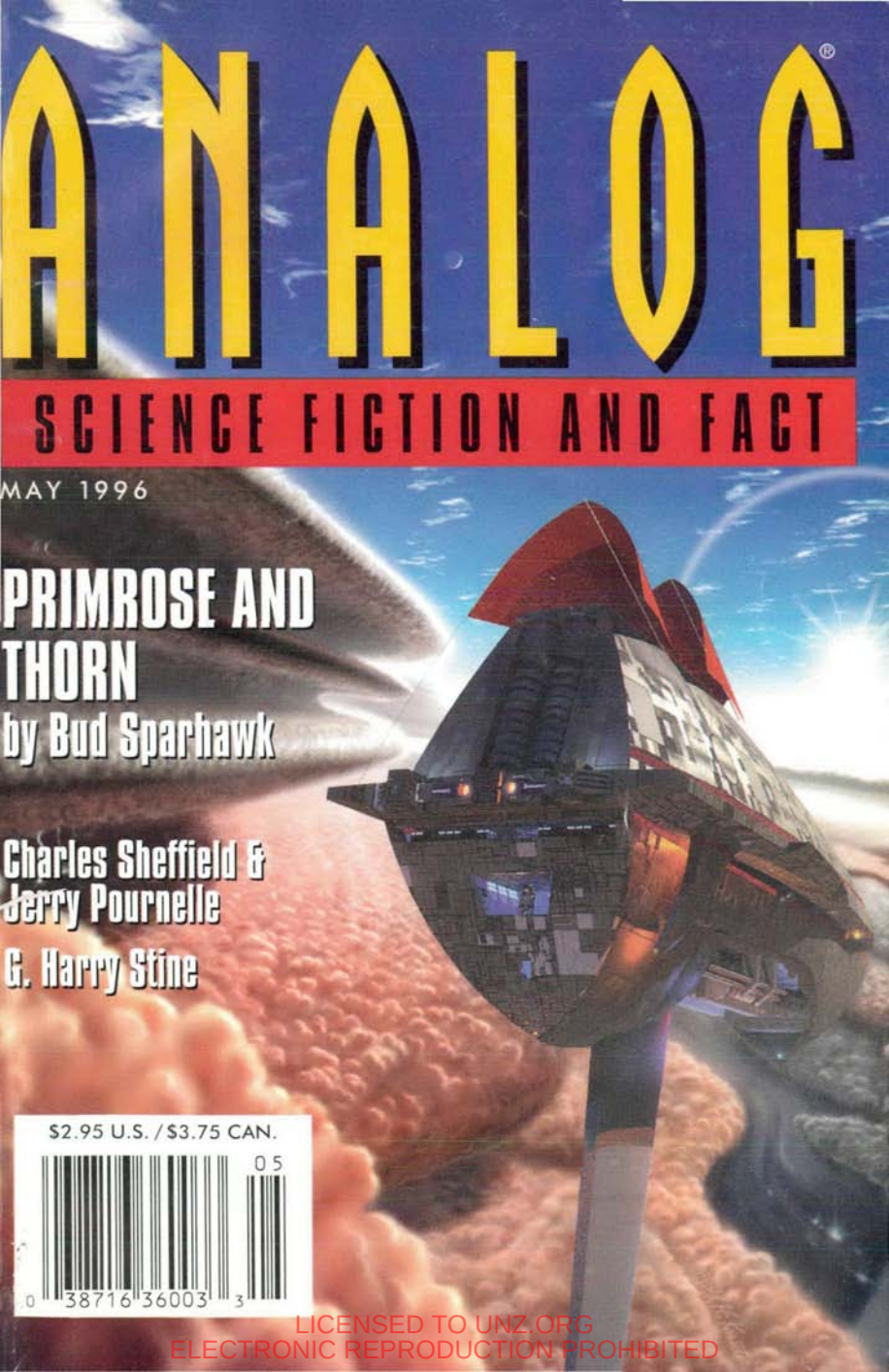


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by Bud Sparhawk

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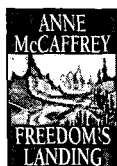
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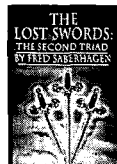
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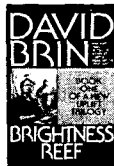
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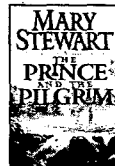
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April 23, 1996

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CATCH-UP TIME

"The optimistic estimate," someone said a few years ago, "is that we'll have nanotechnology in 30 years.

The pessimistic estimate is that we'll have it in 10."

Is the person who made this statement for or against nanotechnology?

If nanotechnology is a good thing to have, shouldn't we be pleased to get it as soon as possible? If it's a bad thing, shouldn't we try to postpone it as long as possible—preferably forever?

As with most "for-or-against" questions, it's not that simple. The person to whom I heard this quote attributed was actively working to develop nanotechnology, so he pretty clearly thought it worthwhile. But he recognized a problem that humanity has faced in assimilating *any* new technology with the potential for radically changing the ways people live. That, not nanotechnology *per se*, is my concern here.

Nanotechnology is a particularly dramatic example of the general problem because, for the reasons K. Eric Drexler first outlined in his book *Engines of Creation*, it seems likely to produce unprecedentedly large changes in an unprecedentedly short time. But the same general problem

had a lot to do with shaping history when computers became common, as well as telephones, automobiles, cotton gins, and (presumably) agriculture and fire.

That problem is the slowness of human thought habits and cultural institutions to *adapt* to the new capabilities bestowed by new technologies. We often hear the complaint that the growth of *wisdom* has not kept pace with that of *knowledge*. "If we can put a man on the Moon," one cliché runs, "why can't we get along with each other? Why do we still have war and poverty and crime?"

The trivial (though true) answer is that those problems are far more complicated, far larger, and far less precisely understood than rocketry and astronomy. But there's a more serious side to the question, too. Historically, societies have run largely on tradition—a set of rules for interpersonal relationships, common practices for dealing with the everyday necessities of life, division of labor, and so on—that has evolved over a long period of time and continues because it works. It may not work perfectly, but if it's had time to get the bugs out, it probably ensures that most people have food and shelter and some idea of

what to expect from tomorrow.

The trouble is that, since societies are big things with lots of inertia, such systems take quite a bit of time to evolve. For a society to develop a reliable set of adaptations, the conditions it's adapting to must stay pretty constant for a long period. Thus, for example, the Inuit (Eskimos) for thousands of years followed pretty much the same way of life based on Arctic climatic conditions and food sources. It served them well, but did not tell them how to deal with things like television, alcohol, and airplanes when they were first exposed to these outside inventions. Many of them have adapted, to a considerable extent, but the process has been traumatic.

New elements don't have to come from outside to create problems of adjustment—or, to look at it another way, anything you didn't have before, no matter how you acquire it, is in some sense "from outside." Thus the same homegrown factories that made it possible for Europeans and Americans of the last couple of centuries to enjoy more widespread material wealth than ever before also created new kinds of slums and personal dissatisfaction.

Not for *everybody*, mind you, and not always *permanently*. There are those who bemoan the social problems that followed the Industrial Revolution, and the ones that are now accompanying the "Information Revolution," and wish these events had never happened. That's throwing the baby out with the bath water. Such people forget the misery that existed before these transformations, and the real improvements they brought to many people's lives. The problem is not New Things, but the process of learning to utilize their benefits while escaping their dangers—and every past or easily imaginable technology has offered *both*.

Hence the opening observation about nanotechnology. Nanotechnology, like any of its predecessors, can do much to make life better for more people. It can also do a lot of damage. The problem with *any* new tool is to learn how to use it without hurting yourself. That means learning to do things differently than you used to—and if you think back to the history of cars and telephones and computers, you'll see that it often means doing a *lot* of things differently. It often amounts to giving up a whole way of life and changing to a new one. That

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POSTMASTER: Send change of address to: ANALOG SCIENCE FICTION AND FACT

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Editorial and Advertising: Analog Science Fiction and Fact, 1540 Broadway, New York NY 10036
Subscriptions: Analog Science Fiction and Fact, P.O. Box 5133, Harlan, IA 51593-5133 ISSN 1059-2113

Printed in the U.S.A.

process is almost always at least a little bit painful, even if the end result makes it worthwhile.

The problem at the moment, as many people see it, is that no end result is in sight. Most of our ancestors were born into a world that they would leave pretty much as they found it. They grew up seeing what occupations were open to them, gravitated into one, and quite often grew comfortable and stayed in that niche as long as they were able. That's far less likely to happen now, because the rate of change has been continually accelerating. The options open to a young person may be obsolete by the time he or she is middle-aged, forcing them to try to find and adapt to a new niche at an age when many people are becoming less able to do such

things. To an ever increasing extent, in less time than people need to get comfortable with one set of circumstances, they find themselves in a completely new set.

Can anything be done about this? Can some way be found to get a better match between the rate of change of the world and the rate of people's adaptation?

When the problem is put that way, there seem to be only two ways it might be solved: teach people to adapt faster, or slow down the rate of change.

The first has appeal; anything that increases people's adaptability gives them a widely applicable advantage. But it's a daunting task. So far our species has had a lot of trouble adapting even to the rates of change we've

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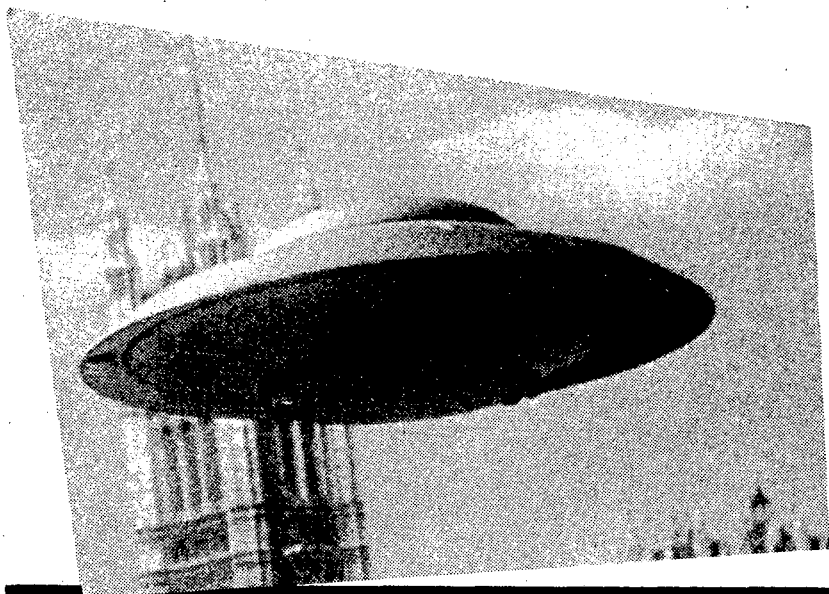
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experienced so far. Consider, for example, our continuing tendency to regard technological unemployment as an appalling problem rather than a golden opportunity. With appropriate redesign of society's works, technology could be giving everyone both a higher standard of living and more time to enjoy it; but instead we try desperately to "solve the problem" by inventing work that doesn't need to be done, just to keep people busy. That's easy for me to say, but who knows how to actually *make* the appropriate changes in society?

Science fiction provides something of a vaccine for "future shock," by helping individuals who read it to anticipate potential developments and so avoid being caught completely by surprise. But it appeals to a relatively small segment of the population; and it's not clear that, at least so far, it's done much to facilitate the actual adaptation of society as a whole to change. There's little evidence that The People's ability to adapt quickly to sweeping changes is getting any better, and I haven't heard many concrete suggestions for how to make it do so.

Which leaves Variable #2: If we can't speed up cultural adaptation, can we slow down the rate of changes that require adaptation? And if we can, should we?

It is, at least, easier to make more or less concrete proposals in this area. Suppose, for example, the governments of the world were to impose a moratorium on research and invention, say, by simply passing a law against it and shutting down research

labs. Not necessarily permanently; the idea is simply to stop the ever-accelerating flood of new things that people must learn to deal with, and give them time to grow comfortable with what they already have. Such a prohibition might have written into it a built-in time limit. E.g., it might say research labs must shut down for ten years, but are free to take up where they left off after that.

Such a proposal raises several questions. Could it be done? If so, how? Would it work? Even if it did work, in terms of successfully allowing a period of "catch-up time," would innovation actually start up again after the "rest period"? *Should* innovation start up again; or, if people have actually managed to create a stable, smoothly functioning society with existing technology, should they quit while they're ahead and just stay with it?

One answer to that last question has become a cliché. Stability equals stagnation, we are told; anything that isn't growing is dying. Like most clichés, that one grew from a grain of truth—and is open to reexamination. Some things do remain in a fairly steady state, with only small oscillations around equilibrium, for long periods. According to many contemporary evolutionists, such as Stephen Jay Gould, most of Earth's ecological history has consisted of such periods of stability, with fairly abrupt transitions from an old equilibrium to a new one occurring only when precipitated by the need to adapt to something new, like a major climate shift. According to many contemporary ecologists, humans as a species are going to *have* to

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learn that perpetual population growth is not a sustainable option. So if we want satisfying, non-stagnant personal lives, we'd better learn to get them without requiring that.

So the mere idea that Stability Is Bad is not a solid argument against the idea of a moratorium on technological change. Social stability does *not* necessarily imply individual stagnation. Every person still comes into the world as *tabula rasa* and gets to spend a lifetime discovering and experiencing all the wonders of the world around him. By some measures, such as incidence of heart disease, some cultures that have been very stable for a very long time seem to treat their members better than more modern, progressive ones. (On the other hand, the modern, progressive ones have other advantages such as longer overall life expectancies; thanks largely to improved control of disease.)

If a temporary "breather" in technological change does not necessarily spell the Death of Civilization, the other questions remain worth considering. Could governments impose it by banning research? One obvious problem is that the kinds of people who become scientists and inventors tend to rebel at the very thought of such control. *Maybe* they could be convinced it was a good idea, as long as it was temporary—but it wouldn't be easy. Abundant experience has taught them to view with suspicion any governmental assurance that a measure is "temporary."

Besides, to have the intended effect, such a moratorium would have

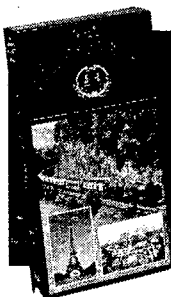
to last several years. What are the scientists and engineers to do while they're waiting? As long as we're locked into a system that considers employment an Intrinsic Good and Fundamental Necessity, such a move would create a massive unemployment problem. Also, creative people often do their most creative work during a relatively brief period early in their careers. Many of them know that. Even if they were convinced that jobs in their preferred field would be waiting for them after spending several years in unrewarding work of other kinds, they would worry (rightly) about whether they'd still have the necessary "spark" to do good science when the opportunity returned.

Then there's a more fundamental question. Even if the world could make itself do without innovation for a while, how long could it last before it became counterproductive? Yes, *there's something to be said for taking time to get really good at using what you have before you discard it and move on to other things.* But, just as climatic shifts have sometimes forced major burst of evolution, sooner or later some problem would come up that *required* radically new ideas to cope with it. If you suppress innovation for a while, how easy will it be to restimulate it when you need it again and all the innovators are out of practice?

The scientifically curious among us would have still another question. If we weren't forced into a new period of innovation, would there ever be another opportunity to learn new basics about the nature of the Universe? For

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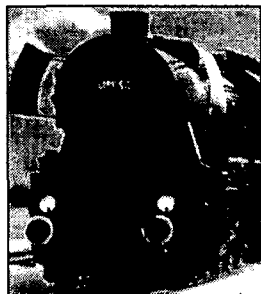
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there is a certain profound satisfaction, quite aside from practical benefits, in learning such things; and there is plenty of reason to doubt that we already know all the basics.

It might be hard to make a moratorium stick for long for one purely practical reason, though there would certainly be pressure to try. Suppose you shut off new scientific discoveries and major inventions *right now*, and tell everybody they have to spend the next decade learning to make the best possible use of what they already have. What they already have will surely include some leftover problems *created* by the technology already in hand. It's quite likely to become clear, after a few years of trying to solve some of those problems without new technology, that the only solutions likely to work *require* a bit more technology. Will exceptions be allowed for those "necessary" innovations—and if so, how can you ensure that those are the *only* ones that happen? As John W. Campbell often pointed out, "You can't do Just One Thing!"

On the whole, Moratorium by Decree seems unlikely to happen, whether it's a good idea or not. But we may get something like it a lot sooner than you'd think—in fact, it may already have begun. Legislation or decree is by no means the only way to stop a kind of work from being done. There's a much more fundamental, and highly effective, way: Stop funding it.

There are two main sources of funding for research: public and private. Public funding for basic research—the kind that usually has little

practical effect, but occasionally leads to the most profound and radical changes—has been drying up for many years. Private industry has usually shown less interest in basic than applied research, but at least one very large and well-known industrial lab has been a powerful bastion of fundamental research: Bell Laboratories. They are the ones that gave us, for example, the transistor, which has so radically transformed virtually every aspect of modern life. And, according to a recent (September 26, 1995) article in *The New York Times*, Bell Labs has now taken a large and deliberate step away from that kind of work.

The new goal of most Bell Labs scientists, according to the *Times* article, "will be to produce incremental improvements in existing products." The article goes on to say that, "The turning away from basic research . . . is not the folly of short-sighted business managers, but a rational adaptation to profound changes in the climate of industrial science . . .," and quotes several workers in the field elaborating on that claim.

Yes, it *is* a business decision, motivated by corporate management's desire to maximize financial return on investment. But the *reasons* why they think "incremental improvements" are now more profitable than radical innovations are telling, and contain strong echoes of my original comments on the stresses of continually adapting to huge changes that come faster and faster. More and more customers, it seems, are pretty well satisfied with the general level of technology they have to work with now.

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They are reluctant to sacrifice the large investments they already have in equipment that serves them well, just to replace it with something all new. They are weary of having to learn a new system from the ground up every time they've started to get comfortable with an old one. In a phrase, they'd like to spend less time and money continually trading in their tools, and more fine-tuning and learning to *use* them to best advantage.

So it seems that the social and economic climate is ripe for something at least a little like that moratorium, if less drastic. The changes at Bell Labs, I suspect, represent in microcosm a

shift in attitudes that's occurring much more widely—and a widespread shift in attitudes can often make inevitable what legislation could not impose. And since the Bell scientists and engineers will still be working on challenging problems in their fields, we can hope that their skills will remain honed and ready to apply when the mood shifts again and fundamental research is again seen as desirable.

Thus we can hope, at least, to get some of the advantages of a temporary slowdown, while retaining the potential to take off again when the time is right. But it will take care and luck. ■

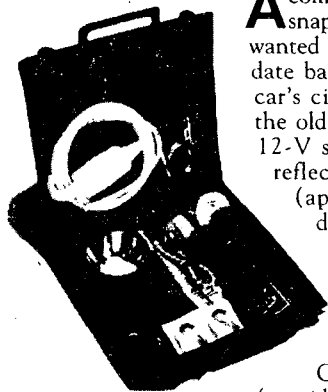
IN TIMES TO COME

A couple of years back, a new writer named Bud Webster sent us a short story with the unlikely title of "Bubba Pritchert and the Space Aliens." "With a name like that," I thought, "it's got to be good—or very bad." As it turned out, on reading it, I thought it was very good; and so did enough of you to elect it your favorite short story of 1994. Well, it seems Bubba Pritchert, southern country gentleman, mechanic, Mensan, and all-around good guy, has developed a reputation that spread even farther than we realized. He's back in our June cover story, "The Three Labors of Bubba," with a new set of aliens needing help. And *their* problem involves a good deal more than a malfunctioning spaceship....

Ben Bova is back, too, with both a short story and a science fact article. The fact article looks at some of the recent developments in several fields of science that seem to be leading us into a new era in our search for extraterrestrial life. Suddenly, where until recently there was only speculation, we're getting lots and lots of *data*—and some of it raises intriguing possibilities indeed!

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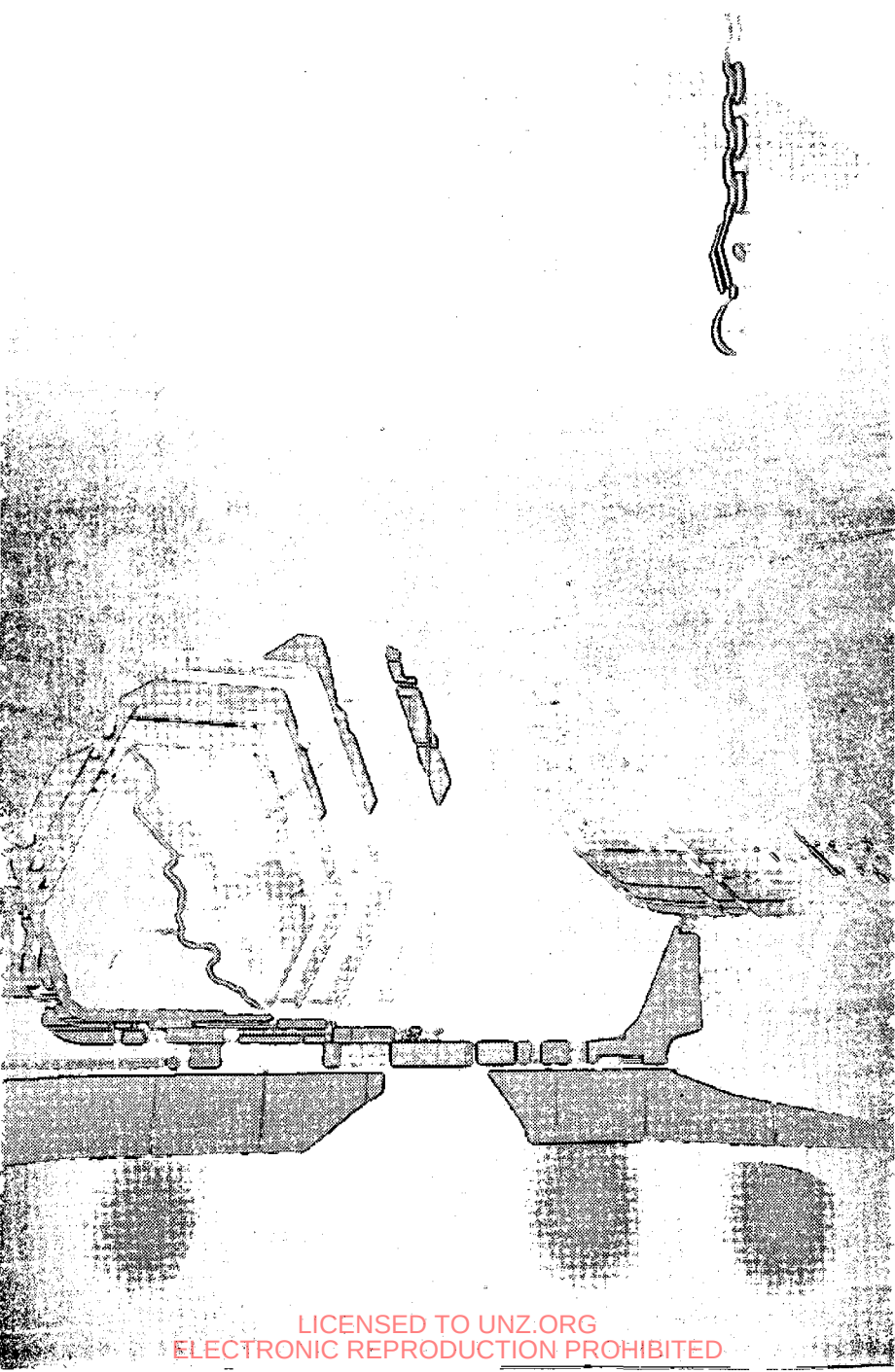
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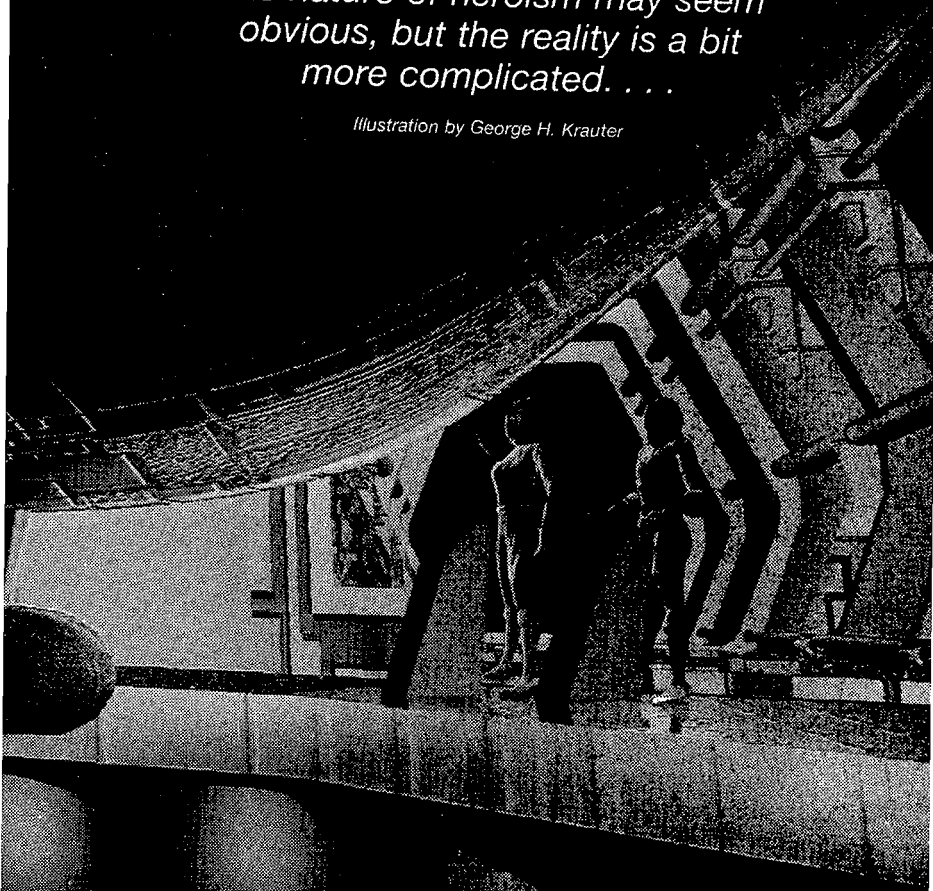
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Bud Sparhawk

PRIMROSE AND THORN

*The nature of heroism may seem
obvious, but the reality is a bit
more complicated. . . .*

Illustration by George H. Krauter



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*"Build me straight,
O worthy Master!*

*Stanch and strong, a goodly vessel,
That shall laugh at all disaster,
And with wave and whirlwind
wrestle!"*

The Building of the Ship,
Henry Wadsworth Longfellow

“Why did I ever listen to you about *this* race? I already spend a bunch right here on Earth,” protested Jerome Blacker, president of JBI. “I’ve been having second thoughts about this Jupiter race.”

The two tanned and muscular people facing him looked uneasy. A sales tag was still attached to the man’s sleeve and flapped as he waved his hand while speaking. “You already made the commitment, JB—you just have to follow through. Come on, it doesn’t cost you any real money.”

“You sure as hell aren’t much of a businessman if you think this won’t cost me anything!” JB said nastily.

“Mr. Blacker,” Pascal interrupted, “the publicity about this race will bring in more than enough to offset expenses.”

Jerome leaned across the desk. “What about insurance, the cost of transport, the cost of the boats? Those things aren’t cheap!”

Pascal sighed. “The funds from the Jovian ventures can’t be spent on Earth. Thanks to the treaty of ’54, you have to reinvest at least 75 percent of your profits.”

Jerome winced. “Don’t remind me about those damn pirates! If it hadn’t

been for my stations and hubs, the damned Jovians wouldn’t have a pot to piss in,” he grumbled.

Pascal continued his attack. “Geo-Globa! and the Times cartel are both outfitting ships for the race. No telling how many the Jovians are going to enter themselves. If we don’t race, JBI will lose a lot—the publicity about our entry will bring in more than enough revenue to cover our expenses.”

Jerome mused, half to himself, as he rubbed his chin. “I remember your numbers, I’ve read the reports. So be it. What do I have to do to finalize the financial arrangements?”

Pascal spoke slowly, not wishing to reveal how anxious he was to get JB’s approval. “I’ve already reserved *Thorn*, a used barkentine. You just need to sign the commitment for outfitting her. Once that’s done, the orbital factories will start fabricating the sails—we’ve already sent them our specs. We’ll use the Jovian funds for both of those efforts. The only cash outlay you need to worry about will be our transport out to Jupiter.”

“Which leaves only the human element,” Jerome said. “Even now I find it hard to believe that we can win this race.” He swiveled in his chair to face the woman who sat beside Pascal. She was the best captain in his fleet and winner of more sailboat races than he could count. She’d been unusually quiet since she came in the office.

“Do you think you can race one of those barques, Louella?” he asked her quietly. “Do you think you can sail a boat on the seas of Jupiter?”

Pascal held his breath as he awaited her answer. The success of their en-

tire enterprise, and the payoff for the past year's worth of intense training, rested on her reply. The answer she gave would make or break the deal.

"I could sail a fucking bathtub on the Sun if the price was right," she spat back. "Now how the hell do I get a drink around here?"

Rams had stopped at the station in the hopes that there would be an opportunity for business. That, and a chance to restock his supplies. In order to keep his ship, *Primrose*, he had to take advantage of every opportunity that came his way.

Jake, an irritable old scamp who knew everything there was to know about sailing the winds of Jupiter, had taught Rams how to sail. Rams learned that every ship had its own personality. He learned how to balance keel and ballast, how to adjust the ship's buoyancy to ride the turbulence.

After teaching him the basics of sail, rudder, keel, and line, Jake went on to show him how to heave-to in the hurricane-force winds so that they would ride easily, neither making way nor being blown back. They'd used that technique to mine the edges of Jupiter's storms. The updrafts in these dangerous hurricanes often pulled metal-rich meteorites and icebergs—worth their weight in gold to the floating stations—from the lower depths of the atmosphere. Jake showed him how to "cheat" the boat close to the edges of the turbulence, using jib and main to close in on these bits of rock and harvest them.

Jake had shared all of his secrets of

playing the winds of Jupiter's storms and winning its rewards. Jake taught Rams to love the winds on the wine-red seas.

Rams's transition from crewman to ship's captain hadn't been easy. He'd scrimped and saved every cent he could, and signed away nearly all of his future profits—all to buy a fast, outdated clipper at one of JBI's auctions. Clippers had been deemed too inefficient to achieve JBI's "acceptable" level of profitability.

Refitting the boat and replacing the instruments that *Primrose's* former crew had stripped put him even further in debt. In addition, there had been the outlay for new sails and refitting the keel. Both cost more than he expected and, suddenly, his debt for *Primrose* started to look like a financial black hole from which there was no hope of escape.

His first year had been a disaster. The cargo he'd hauled hadn't generated enough to pay the interest on his loans. To keep from losing her he borrowed even more. If he wasn't careful he could lose *Primrose* and be thrown in jail—that was the penalty for simultaneously using her as collateral for multiple loans. Since then it had been nip and tuck, keeping one financial step ahead of bankruptcy.

The second year of operations had taught him where the good money could be earned—carrying perishable goods on quick dashes. JBI's huge, lumbering cargo ships could move things cheaply, but they were neither speedy nor very maneuverable. Like the old square-riggers of Earth, they flew with the wind, stolid as the sta-

tions, and scarcely moving much faster. Sometimes their crew endured months between station-falls.

Rams usually got the best return when he had to make a darting emergency run from station to hub and back. Double charges both ways, and no hassle for it, either! Best of all, the fees kept him out of prison.

"Wind one-thirty meters per second and rising, Cap'n. Satellite shows some deep turbulence spimming off the edge about twelve thousand clicks upwind and heading to intercept your destination. Weather advises you should try to stay within the central laminar flows of sub-bands MM and KK until you're almost to Charlie Sierra One. That should keep you out of the storm," the station master said.

"Put it down that I acknowledge the limits on bands MM and KK," Rams replied as the 'master logged his ship out. "How much margin does Weather give me before that storm hits?"

"Best they can project is that you have about a sixteen-hour margin, give or take six hours. Of course, if it swings south of CS-42 the edge winds might give you a lift."

"When did I ever see one of those storms change course in a way that would help me?" Rams asked rhetorically. "I'll plan on beating the weather the last leg of the trip. I just hope that Weather's prediction is right."

"I agree with that," the 'master replied. "You'd better keep a watch for any miners who might be prospecting on the periphery of the storm.

Wouldn't want to run into one of those crazies, would you?"

Rams grinned, remembering when he had been one of those crazies. "I'll watch out for them," he promised.

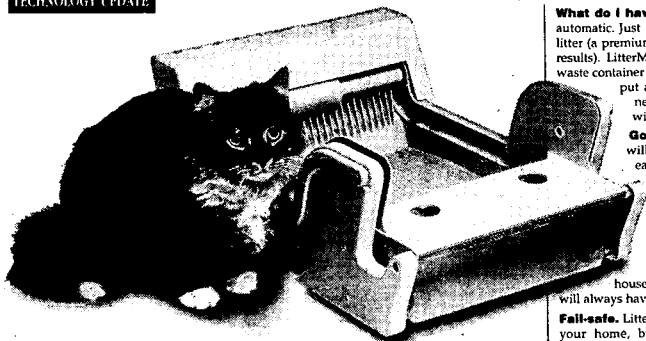
"Well, it looks like you are all set to go, *Primrose*," the station master said as he popped the record from the computer and handed it to Rams. "Fair winds and good passage, Cap'n."

Rams checked the ballast tank when he returned to the ship. According to the leveling mark on the wall of *Primrose's* berth, she was riding low—just a little too heavy, probably from the extra cargo he'd taken on. He switched on the heaters in the ballast tank. That would create enough steam pressure to drive the excess ballast out, lightening the ship. When *Primrose's* bull's-eye was almost up to the mark, he turned the heater off. In a few moments more she was floating level with the station.

"Ready to cast off!" Rams said over the intercom. He listened for the 'master to loose the clamps that held *Primrose* in the station's embrace. Four loud bangs resounded through the pressure hull as the clamps released. Rams immediately felt the ship list to starboard as she drifted backwards into the fierce winds of Jupiter.

Primrose heeled as it caught the full force of the wind. Rams braced himself, checked the instruments, and then turned the ship downwind as it emerged from the lee of the station,

The station's infrared image quickly faded as they exceeded the viewer's range. A few seconds later the sonar return vanished as well. Only a fuzzy



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by Shirley Liberles

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There are few things I can think of that are as foul as cleaning the litter box at my house. Even when I clean it daily, it's difficult to keep odor away.

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radar image, quickly dissolving into a cloud of electronic noise, told him where the station rode. Even that image would fade once he got more than a kilometer away. After that he'd be sailing blind.

Primrose ran with the wind as he lowered the keel. He pointedly ignored the keelometer as the diamond mesh ribbon uncoiled from its housing. The thousand-ton weight at the keel's end started its familiar swinging motion as the keel was unwrapped from its spindle. *Primrose* rocked in response to the motion. The pendulum's swing slowed as the ribbon paid out farther and farther into the thick soup of the atmosphere.

Finally the rocking motion dampened and Rams halted the winch, locking it in place. Only then did he check the keelometer. Although he relied more on the feel of the ship's trim when setting the keel depth, he liked to assure himself of the setting.

A single glance told him that his instincts had been correct. He'd halted the keel at 1,400 meters, one hundred meters shy of the theoretical setting the station master had calculated. He let an additional fifty meters of the mesh keel pay out; it wouldn't hurt to have *Primrose* a little bottom-heavy on an upwind run.

Rams reached for the sail controls. *Primrose* was being blown downwind at thirty meters per second, relative to the station. The station he'd just left plodded along *slower* than the wind, held back only by her massive drogues—a fancy word for sea anchors. The drogues that swung beneath the station's bulbous form

created drag and provided a measure of control. It was sailing, but using anchors to steer instead of sails.

Rams hit the switch to release his mainsail from its housing on the main mast and braced himself. The ship tilted even further to starboard as the wind bit the suddenly increased surface area. He immediately played out the traveler, letting the main find the angle that would allow the fierce wind to flow across the sail's face. He kept a careful eye on the pressure gauges from both sides of the wishbone that constrained the sail, adjusting the sail's angle to maximize the front-to-back pressure differential. He wanted to get as much lift as possible from the airfoil effect.

Primrose finally stopped rocking and curved into the wind as Rams adjusted the line. *Primrose* was running at about sixty degrees to the wind when she finally balanced out and was making an appreciable sixty meters per second.

"All right, girl, let's show old man Jupiter what we can really do," he said, deploying the jib from its housing at the prow. There was a hellacious rattling from forward as the chain hoist protested the way the wind whipped at the small jib and smashed it against the pressure hull. Rams winched the line back until the jib sheets were taut and the small forward sail was funneling the wind along the back of the mainsail, forming a venturi between them.

Primrose heeled even more as the force on her increased from the additional sail surface exposed to the wind and turned tighter into the face

of the wind. She was now running at about a forty degree angle. Rams grinned in satisfaction as her speed increased proportionally. He watched the knotmeter rise past seventy, seventy-five, and settle at nearly eighty meters per second.

He checked his location on the inertial positioning display and made a minor adjustment to the rudder, then adjusted both the mainsail and jib to account for the new angle of attack.

"Clipper Ship *Primrose* out at 1400 hours, under way and on course for Charlie Sierra Four Two," he said into the radio. The station master probably wouldn't be able to hear the formal sign-off, given the usual overwhelming amount of static in the atmosphere. Nevertheless, Rams was always careful to observe the formalities.

As *Primrose* pulled steadily away, Rams made a thorough examination of the ship. He wanted to ensure that everything on board was shipshape. He double-checked the straps and buckles on all of the cargo crates, just to make sure they'd been properly secured.

Next he checked the topside sail locker, taking care to see that the spare sails were properly stored and ready for deployment when the need arose. If all went well he wouldn't have to replace the sails on this trip, which would help his profit margin. Having them fabricated in orbit and brought down by elevator was bloody expensive.

He swung the power-lifters from their clamps and started working on the new sail. He strained against the resistance of the tough foil of the sail

as he refolded it. Even so, he tried to keep from flexing the thin metal more than was necessary.

As soon as he had the sail properly folded and secured, he moved it into its canister. His arms ached as he struggled to get it into the correct position, cursing the financial situation that forced him to fire his crew three months before and the expediency that kept him from having the time in dock to do this sort of housekeeping. One person could barely cope with the bulky sails against the drag of Jupiter's heavy gravity. Even with the one hundred-to-one ratio of the lifters, he still had to depend on his own muscle to force the cumbersome rig into the canister.

Finally the sail was loaded. He stowed the lifters and rubbed his aching back before fastening the heavy chain lines at the head end of the sail; one line that would lift it into place on the mast and another to connect it to the traveler that limited a sail's movement across the top deck.

Whenever he had to blow the main its lines would go with it. The lines were another expense he wished that he could avoid. But the only way to save them was to suit up, climb out onto deck, and try to disconnect them while fighting hurricane force winds. Only a fool went outside without a backup crew, no matter how securely he was clamped to the deck! The lost money for lines wasn't as important to him as his life.

By the time Rams worked his way back to the cockpit, *Primrose* had moved far north of the station. From this position he could start to tack

without the risk of running into it. Just to make certain of his clearance, he peered at the screen, cranking the radar to maximum sensitivity to check.

The screen showed a uniform blur of undifferentiated noise; not even a shadow that could be suspected of being something other than the swirling electronic mist of atmosphere.

Rams and *Primrose* were now completely on their own and, in five days, more or less, he hoped to see the faint, white heat signature of his destination. He hoped that the storm wouldn't spoil his plans—he needed the money to make the next payment!

"What a dump," Louella complained loudly. She threw her bag against the bare metal deck and watched as it lazily bounced back into the air. "Not even a bar on the place! To make matters worse I have to share the damned cabin with you. I can't even have some gods-be-damned decent privacy before the race!"

Pascal winced at the strident tone of her voice. He regretted accompanying her throughout the long voyage from Earth to the Jovian system. He should have come on another ship.

Louella's growing catalog of complaints had increased throughout the long transit from Earth. Thankfully, there'd been enough distractions on the transport to silence her complaints, once in the while. The transport had a bar to keep her amused, and enough willing young crew members to keep her bemused. But those diversions were short-lived. Too soon

she came back to the fact that she wasn't racing, wasn't in control, wasn't at sea.

It made her bitchy.

"How the devil am I supposed to keep my sanity if they can't even provide civilized, *basic* amenities?" Louella continued in a rasping voice that cut across his nerves like fingernails on slate.

"Bad enough that I have to miss *three* seasons of the circuit for this fool race! Bad enough that we have to stay in this stupid can until the others get here! But that doesn't mean I have to live like some *freaking* Spartan in the meantime!"

She lifted the lid of the utilitarian toilet. "Jesus, we even have to share the damned can!"

"Perhaps you should complain to the hub master," Pascal said quietly as he floated across the tiny cabin and anchored himself with one hand. "Maybe he can provide whatever it is that you need."

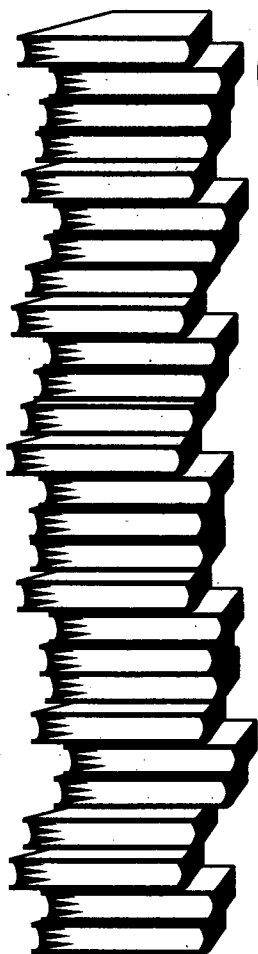
Louella spun gracefully around on her hold and frowned at him. "What is that supposed to mean?"

Pascal winced again. What had he said *now*? It didn't matter; she'd be hell to live with if he just let it be. "Nothing," he said. "I just thought that maybe the captain has resources we don't know about. It wouldn't hurt to ask."

"Humph," Louella huffed, as if unsure of the meaning of his answer. She kicked her floating bag into some netting to secure it. "You've got the bunk beside the door, asshole. And don't get any ideas about us sleeping together."

"I wouldn't dream of it," Pascal

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replied dryly and turned to fiddle with the controls on the wall. Under his breath he added, "Nightmares, perhaps, but not dreams." He pressed the switch to open the viewport.

"What did you say?" Louella asked sharply. "Something I wasn't supposed to—oh my god! Would you look at that!" Pascal didn't answer, he was as awed by the sight as she.

Framed in the viewport was the entirety of Jupiter, half orange, rose, and umber, and half in darkness. The rim of the planet filled the 'port from top to bottom, leaving only a narrow circle of stars at the edges to show that anything else existed in the heavens.

The bright line of the elevator cable extended from somewhere beneath the window and ran straight toward the planet's equator, far below, just as it extended thousands of kilometers out into space from this geosynchronous station. The cable's silvery line narrowed as it diminished into perfect perspective toward the giant planet.

Jupiter's great red spot wasn't visible. Pascal assumed that it was either on the other side of the planet or somewhere within the semicircle of darkness that marked the night side of Jupiter. But there were enough other large features present to occupy the eye.

Wide bands of permanent lateral weather patterns ran across Jupiter's face. Each showed feathery turbulence whorls at the edges as they dragged on the slower bands toward the equator or were accelerated by faster ones toward the poles. From here he could easily see the separations between them.

In the center of one of the higher latitude bands there was a dark smudge. Pascal thought it might be the persistent traces of the "string of pearls" comet, over a hundred years ago, but he wasn't sure. He couldn't remember if the marks would be on top or bottom from his viewpoint. He decided to ask the hub master about orientation.

"What a sight," Louella whispered as she moved beside him. "Gorgeous, just gorgeous," she said, with a touch of awe. "Where are the floating stations? Could we see them from here?" she asked quickly and pressed closer to the viewport.

Pascal dismissed her inquiry with a shrug. "The stations are too small to see from here. You're still thinking in terms of Earth. We're over six hundred times farther out than one of the orbiting stations would be at home. CS-6 would have to be the size of Australia for you to see it with your naked eye.

"You've got to remember that each one of those weather bands is several thousand miles across," Pascal continued as he backed away from the viewport and the terrifying precipice it represented. "We could put the entire Pacific inside any one of them and still have plenty of room left over."

Louella's face took on a rapt expression as she absorbed the scale of what she was observing. "You could sail forever in those seas," she breathed heavily. "Forever."

Rams encountered his first problem when he was thirty hours under way. *Primrose* had been beating steadily to

windward since he left CS-15. By his projections they should have been slightly north of the projected track of CS-42, the next station in line. This leg of his upwind trip would be two thousand kilometers long before he came about and headed south on the shorter lee leg. That was as far as he could travel and stay within the limits Weather had advised. He couldn't go beyond the MM sub-band without risking excessive turbulence. No, he thought, it was better to keep to the smooth and dependable jets of air in the middle of the band.

It was no small effort to steer *Primrose* between the two stations. CS-15 had been moving westward at a steady twenty-six meters per second under the slower westward winds of the KK sub-band.

The two stations had been about eight thousand kilometers apart when he had departed. He had planned to tack about eight times across the face of the wind; four 2,000-kilometer legs to the north and four 3,000-kilometer legs to the south. The southern tacks would gain him the least progress but give him good position to intercept the station as it raced toward him.

It was a good sail plan. The only problem was that it wasn't working out. The inertial guidance system indicated that, instead, he was steadily bearing west of his projected course. Rams checked the set of the sails and the pressure readings. Using these numbers, he calculated that *Primrose* was still bearing forty degrees to the wind, just as he had planned. What could be wrong? Was he was being blown off course by an unexpected

head wind?

An hour later he understood the situation. Something was disturbing the "smooth laminar flow" predictions of Weather. He just encountered a more northerly wind than expected. He decided to adjust his tacking strategy to adapt to the shift. He'd have to take a longer line on the southern tack. But the slower passage would put him at risk from the storm, which could mean big trouble.

He plotted his course for the next ninety hours with great care.

As they sped down toward the seas of Jupiter, Pascal sat as far from the port of the tiny cab of the elevator as he could and tried to ignore the pit of blackness, a hole in the sky at the center of an enormous emptiness. The thought of all the distance they had to fall terrified him.

"I still don't understand how you guys do it," the pink-faced elevator pilot said from his perch at the bow. "I mean, I can see how a sailboat can go with the wind. The hot air balloons on Earth just go with the wind, right? Why wouldn't they do the same here?"

"It's the keel," John said. He and Al were their competitors from Geo-Global. They'd arrived a few days before, along with the third crew that would participate in the race. "A sailboat would be just like a balloon if it didn't have a keel."

"Oh, I see. That's why the Jupiter ships have that long ribbon under them," the pilot remarked. "But how does that help them move against the wind? And isn't it impossible to go

faster than the wind?"

"Good question," Pascal said, glad of the distraction. "A sailboat goes faster into the wind, not slower. The slowest speed of all is when you run with the wind directly behind you."

Pascal let the kid think about that for a moment before he continued. "A sail is an airfoil. One side forms a pocket of relatively dead air. The opposite side is bent out so that the wind has a longer distance to travel. The pressure differential pulls the sailboat along."

"A foresail funnels the air across the main and accentuates the effect," Al injected. "The closer you haul to the direction of the wind the faster you go."

John spoke up, "It's just a matter of physics: the angle of force on the sail and the keel produces a vector of force that moves the boat forward. The steeper the angle the greater the forward thrust. The trick is to balance the force of the wind and the sails, adjusting your angle of attack to obtain the greatest forward momentum possible, maximizing the transfer of static air pressure to dynamic motive force."

"Oh, I understand," the operator said, screwing his face up in concentration. "It's like continuously solving a set of differential equations." He smiled at them as if he were proud of learning the lesson so well.

"Don't bust a gut trying to do that if you're ever in a sailboat, kid," Louella said. "It's all scientific bullshit."

Louella glared at the three of them; a fierce set to her eyes and mouth that brooked no interruption. "These guys want you to think that sailing's a sci-

ence—that it's all application of mathematical rules and physics. Listening to them, you'd think that you're constantly thinking, calculating, and plotting. Well, that's all a pile of crap—sailing isn't some branch of engineering."

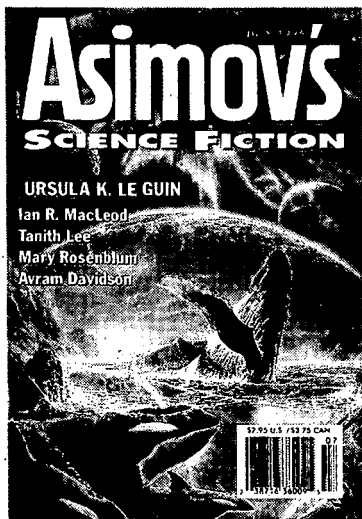
She leaned forward to look straight into the operator's eyes, her expression softening as she did so. "Sailing's a love affair between you, the boat, the water, and the wind. Every one of them has to be balanced, held in check; let any one of them dominate and you've lost it. A good sailor has to be conscious of wind and water and responsive to the boat's needs. You have to understand the language of wind and sea and ship—you have to feel that *edge* that means you're running a tight line with every nerve of your body. The boat'll tell you how she wants to behave; she'll fight you when you're wrong, and support you when you're right."

She brushed at her cheek, as if something had gotten in her eye, before she continued. "The point I'm trying so damn hard to get across to you is that sailing is an art, not a bloody damn science. That means you have to sail with your heart, as well as your mind. When you're on the sea, managing the sails and the wheel, the rest of the Universe could disappear, for all that you care. When everything works right, there's a rhythm, a reverie that transforms you, that makes you one with the Universe. If you put everything you have into it, mind and body, your ego disappears—its just you, the boat, the wind, and the water."

She turned back to stare out the

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viewport at the advancing planet and slumped into her seat. "If it was just science, JBI wouldn't be paying the big bucks to haul my ass all the way out here. No, they'd get some double-dome Ph. and D. to build a little machine to do it, and the hell with the beauty of a good line and a strong wind.

"But the fact that I am here to sail on Jupiter's orange seas says that there's still a human element to sailing that's better than the most refined engineering approach. It says that a human being can still stand on a ship's deck and dare the wind and the seas to do their worst. It tells me that even some damn overgrown pig of a planet can't tame the human spirit!"

The silence prevailed for long minutes. "Well," said Al, apropos of nothing. "Well."

Louella said nothing for the rest of the trip down into the thick atmosphere. Pascal tried to ignore the view as sunrise raced across Jupiter's face, too far below.

Rams's destination was floating along at twenty-odd meters per second to the east of his present position. Her track was so reliably managed that the station's precise location could be calculated to within a kilometer.

Somewhere on the other side of CS-42 a whirling hurricane was advancing. Given the right spin and direction these storms could grow beyond reasonable bounds, turning into blows that made Earth's hurricanes look like a faint puff of air. Ninety-nine times out of a hundred Jupiter's hurricanes

dissipated quickly, within two or three of his ten-hour rotations. If Rams was lucky, this one would do the same.

Rams was dismayed to discover that *Primrose* fell even farther westward off of her planned track whenever he turned to the north. That meant two things: the winds were continuing to shift, and the storm was deeper than expected. It looked as if he'd hit the edges of a major storm.

For the thousandth time he wished that Jupiter wasn't so electronically active. The ambient white noise on the radio bands was so intense that even pulse-code modulation couldn't punch a signal through. Just one crummy satellite picture, one quick radar image, one short broadcast was all he'd need to find out what was happening with the storm.

Instead, all he knew about the storm was its rough starting position, Weather's predicted track, and the data the station master provided about prevailing winds. He also had the data from his own inertial system. From those weak components he had to navigate through a dark eight thousand kilometers, face unknown winds, and find the tiny station that was his destination.

"A little bit cramped, isn't it?" Pascal remarked as they inspected *Thorn*, their tiny, nine-hundred ton, double-masted barque. He sat with one leg extended into the cockpit and the other in the "stateroom," which also served as kitchen, bath, and bedroom. A single bunk stretched for two meters across the overhead with a single

small seat below, which, when lifted, revealed the toilet. A tiny shelf with a built-in microwave oven and a recessed sink—hidden under the working surface—ran along the second bulkhead, to the right. Their food and medical supplies were stored in hanging bags, Velcroed to the bulkhead above the microwave.

On the opposite bulkhead was a fold-down table whose opened edge would be in the lap of whoever was sitting on the seat. The navigation instruments, computer, and the storage for charts and instruments were revealed when the table was down. Rams could reach out with his left arm and just about touch the edge of the helmsman's seat, it was that close. For a big boat *Thorn* had mighty small crew quarters.

"Maybe we shouldn't have picked a cargo hauler—it's a little cramped, isn't it?" Louella remarked as she ducked her head to peek into the compartment. "Place looked a lot roomier in the plans. I guess the crew wasn't supposed to stay aboard for more than a day or two."

Pascal looked around. "Why couldn't they convert some of that cargo hold? This is pretty tight. I don't relish spending a couple of weeks in here."

"Too much trouble just to give us a little bit of comfort. I don't think the expense would be worth it—might upset the boat's balance."

Pascal sighed and wiggled in the tiny seat, trying to find a way to stretch his legs full length, and failed. "The navigator's station on the Bermuda run was bigger than this," he complained. He tried to put his arms out

and his right elbow hit the hanging bags. He sighed again—this was going to be damned uncomfortable.

"Yeah, but you weren't nearly as warm and dry," Louella reminded him. "I don't mind cramped spaces during a race. Hell, on most of our races, dry underwear's a luxury! Count your blessings, Pascal. Count your blessings."

While Pascal squeezed up the narrow tube to examine the sail locker, Louella sat in the helmsman's seat. She let her hands run over the controls. She loved the slightly sticky feel of the wrappings on the wheel. Here and there she noted the faint, oily marks *Thorn's* captains' sweating hands had put there.

A bright, shining circle was worn into the dull metal beside the winch controls. She reached for a knob, as if to activate it, and noticed that the heel of her hand centered on the worn spot. How many hundreds of times had another hand briefly touched there to wear the finish like that, she wondered. How many captains had sat in this seat to guide the tiny craft across the dark seas of Jupiter? In her mind, those other captains were a palpable presence in the tiny cabin, a trace of the boat's memory.

Directly in front of the helmsman's seat were the screens that displayed the fore and aft camera views. Their controls were in easy reach, just below them. To her left were the inertial display unit, the pressure gauges, and various station-keeping controls. The housekeeping controls were mounted beneath the seat, where they could be reached from the stateroom.

On a swing arm above the wheel were the primary control readouts: sail pressure gauges, wind indicator, barometer, and dead reckoning display. Once they were under way she'd be completely dependent on them.

There was a clatter as Pascal wormed his way out of the tube. "Sail sets look OK," he said, as he slid across the deck and dropped into the stateroom's seat. "We've got spares for every sail, plus the extras that you ordered. All of them are marked and set for loading."

"Did you make sure that we have enough lines? I don't want to get caught short on tack once we get out of here."

Pascal snorted. "Of course I checked. My butt's going to be out there too, you know."

Louella nodded, all business. "I double-checked the inspection reports. Just the same we need to do a walk-around."

She'd said it so calmly that Pascal *almost* missed the implication of what she had said. When he did, he snapped erect, banging his head on the bottom of the bunk.

"Y . . . you mean . . . go outside?" he blurted.

Louella sneered at him. "Sure. We can get some pressure suits and hand lights to work with. As long as you stay in the dock you won't have any problems. It will be just like going for our training stroll at geosynch. You didn't have any problems there, did you?"

Pascal stuttered. He'd been scared out of his wits the whole time, worry-

ing whether his lines were securely attached, worrying about the ability of his boots to hold fast to the deck, worrying about slipping, about the vast distance that he would fall should he become detached from the station.

"N . . . no," he lied.

They didn't need the hand lights after all. *Thorn* was still parked in the repair bay where there was plenty of external illumination. Louella held tight to her walker as she stumbled through the lock. The walker took most of the weight off her legs, which was a blessing. Even though she didn't have too much of a problem with the two g's, the additional weight of the heavy pressure suit made movement difficult.

Pascal stumbled along behind her, clutching his own walker so tightly that it looked as if he'd leave glove marks in the metal.

"What a pig," Louella remarked as she examined the bulbous skin of *Thorn's* outer envelope. "Looks like a damned overgrown, pregnant guppy," she said as she walked along the side of the bulging hull, thinking of the sleek craft she had sailed in Earth's tame waters. Every few steps she stopped to examine a weld, a spot of suspicious discoloration, or one of the vents for the ballast hold.

"Let's take a look at her rigging," she demanded and followed the crew chief to the boat's deck.

Two stubby masts projected up from the center line of *Thorn's* upper surface. These were thick triangles of heavy metal, nearly six meters across at their thickest dimension. They certainly weren't the slender masts she'd

known all her life.

The trailing edge of each mast was a pair of clamshells. These were double-locked doors that would open when they deployed the sails. A short track ran back from each mast, with a crosswise track at the end. "We extended the travelers on both sides, like you asked," the crew chief said. "You're goin' to have a bit of trouble handling her. Keep a tight hand on the wheel and don't run close to the wind, is my advice." Disapproval was evident in his voice. "Don't think you should have done that, though. These little boats ain't built to take much heel, y'know."

Louella bristled as she checked the workmanship on the track modifications, looking for any indication that the repair crew had scrimped on her specifications. "Did you think about adjusting the traveler's winches to take the extra line?"

The crew chief bristled. "Of course I did," he said gruffly. "I don't appreciate you sayin' that I don't know how to do my job."

"Really? Well, I don't like you telling me how to sail a boat either, asshole!" she shot back. She moved to examine the other mast as the crew chief licked his wounds.

While Louella and the crew chief were above deck, Pascal examined the hull. The keel had already been retracted from the meter-by-meter safety inspection. The huge weights at the ends of the double keel swung slowly from side to side as *Thorn* bobbed up and down. *Thorn* was just a balloon when she wasn't under way. The

keels' slender foils hardly seemed strong enough to support the three hundred tons of droplet-shaped weights. The blunt nose of the forward weight was smooth and bright, as if it had been polished. There were several long gouges along the sides.

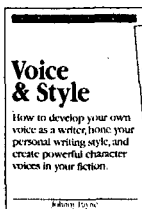
"Impact scars," the crewman said as she reached across the gap and shoved her glove inside one of the larger ones. "There's always some gravel being driven around the atmosphere, especially down deep, where the keel runs. Sometimes they're pretty big and movin' fast. That's what made these dings, y'see."

Pascal was still staring at the thin ribbons that supported the weights. Each was only a few centimeters thick, hardly the width of his hand. One rip from a rough piece of gravel, he thought, and the ribbon could be severed and the weight would be released, dropping down into the depths far, far below.

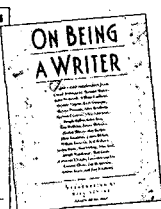
Suddenly he realized that he was only one step away from the edge of the inspection platform. One step away from a fall that wouldn't stop until he reached a pressure level that would crush and kill him, compressing his suit and body into a tiny mass. He would still fall until it hit the layer of metallic hydrogen, hundreds and hundreds of kilometers below the station. No, that wasn't really true; he wouldn't fall that far. His body would come to rest somewhere where his density was equal to the surrounding atmosphere.

But he'd still be dead.

A wave of vertigo overcame him. He stumbled back from the dangerous



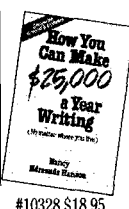
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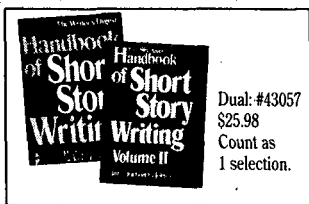
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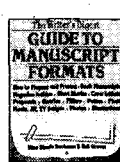
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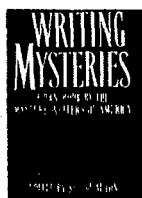
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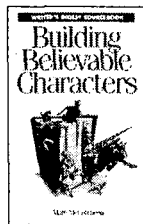
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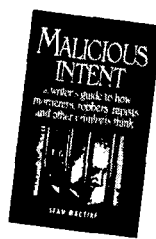
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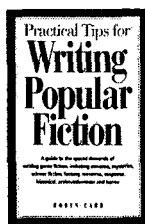
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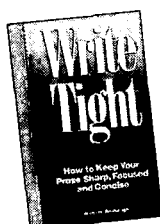
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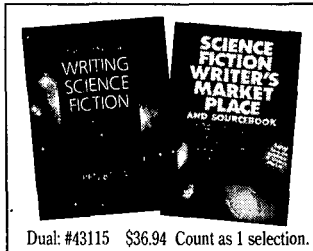
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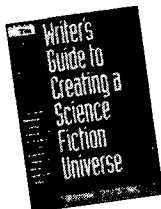
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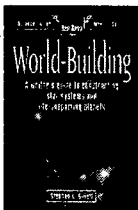
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precipice. "I . . . I need to get back inside," he told his escort, clamping his hand on the safety line. "Now!" he shouted when the crewman didn't respond at once. He had to get away from that horrid drop.

Twelve hours later Rams realized that he was in serious trouble. Whenever he tried to head due north, he was forced farther west of his planned track. To be so affected at this distance meant that the storm was immense.

He prepared for the coming storm. The two things a sailor had to remember about surviving a storm, whether on Jupiter or on Earth, were either to be prepared, or be elsewhere. Rams began to go through *Primrose* and secure her. Even a small item flying about in a two-g field could do substantial damage.

The galley and his own cabin were easy. Rams made it a practice to stow everything until needed. Just the same, he went through every locker to make sure that nothing would fall out and surprise him. He poured hot tea into a thermos and stowed that, along with some bread, in the cockpit.

Securing the cargo hold occupied him for an hour. He put double lashings on all the containers, and tied them together, just to make sure. That done, he made certain that all loose lines were in the lockers, along with all of the deck gear. Nothing that could become a flying missile was left unsecured.

Since he wasn't carrying passengers this trip, the other four cabins

were empty. Just the same, he checked them for loose gear or an open locker. He had to make absolutely certain they were secure.

Securing the sail locker presented a problem. Rams had to balance being able to hoist sail in a hurry—which meant he had to have one loose—against the risk of it breaking free. He secured the larger sails and kept the two small ones ready to hoist as a compromise. If the blow was as heavy as he expected, the small ones were more likely to be used.

That done, Rams brought the ship about to begin another long, southerly tack. That way he could use the peripheral winds to stay on the outer fringes of the storm. With a little bit of luck, *Primrose* wouldn't be drawn into its roaring core. Then he settled down to see what the long night would bring.

Thorn was six days out from the start and making way at a steady 150 mps. Pascal had already grown sick of the close quarters, the five-hours-on, five-hours-off schedule that matched Jupiter's rotational rate, Louella's lousy cooking (even if it was better than his own), the dragging load from Jupiter's gravity, and the lingering, stinking ammonia smell from the boat's slight atmospheric leakage.

They'd added their own contribution to the atmosphere. After nearly a week of confined quarters they had created a unique miasma. The cabin was redolent of recirculated air, collected flatulence, sweat, and the miscellaneous aromas that the human body produced. Only the ability of the

human nose to filter out the worst of these protected him. Still, the smells remained, and, unfortunately, Pascal's nose sometimes forgot to ignore them.

He fidgeted at the wheel, keeping a wary eye on the instruments. It was important to maintain the sail's pressure differential right on the edge; that way they could keep their speed up. All week Louella had beaten his time. Somehow she was able to wrest a few extra knots from the wind. No matter how much he pushed, Louella was always able to do better.

They'd been competing ever since he could remember, each trying to outdo the other. She dared him to become a better sailor, even as she relentlessly strove to beat him every time. He challenged her to become the better navigator, and laughed at her struggles with simple plotting problems. She'd succeeded better than he, even if he never was able to offset her intuition with his science. Their teamwork had won numerous races over the years. Their success gained them prime berths in JBI's commercial racing fleet. Louella had worked her way from an Olympic dinghy championship at age thirteen to finally being the helmsman on most of JBI's Cup winners as well as the number one competitor in most of the other commercial classes.

Pascal had been recruited by JBI as a navigator for Louella's first Whitbread. Since then he'd been with her for every race, alternatively as navigator, tactician, winch crank, or sail master. He'd been helmsman when she was captain and shared bunk with

her on the *Times's* double-around-the-world. They'd weathered hurricanes and drifted demasted for days with only a bottle of water to share between them. They'd broached a hundred thousand dollar racer in 'Frisco Bay, lost a two million dollar racer in the South Pacific, and survived to win the Bermuda in spite of a hurricane that destroyed half the fleet and shredded their mainsail to ribbons. It had been a thrill the whole time.

He just wished that she wasn't such a pain in the ass.

Louella came awake in an instant and checked her watch. She had managed to sleep for nearly five hours without being jarred awake. "Damn Pascal's eyes," she complained to herself as she fastened her truss. "He must be running safe again." That meant that she would have to make up for lost time during her watch, as usual.

She rolled out of the bunk, stepped cautiously to the deck and used the toilet, splashing a little water from the sink up her nose to counteract the dryness from the ammonia fumes.

"Tea's hot," Pascal called down to her in a voice heavy with fatigue.

"Thanks," she replied, looking for the thermos. "How did you find time to make it?"

"You mean how much progress did that cost us, don't you," he replied sharply. "Not a bit, I'm sure."

"Do you think that the competition's doing better? Damn, but I wish we had some way of telling where

the other boats are!"

A week before everyone had set off from Charlie Sierra Six on the first leg of the Great Jupiter Race, as the press had been calling it. The first leg would take them around CS-15 and then back to CS-27, where they would come to windward and race downwind to CS-6, where they had begun.

Louella had watched the heat signature of their prime competitor fall to *Thorn's* lee when they came out of the shelter of the starting station, indicating that they had caught the vortex off *Thorn* and were spinning away to get good air. It was a trick most sailors learned before they left their cribs.

They had watched the diminishing white dot that represented the station fade into the background noise as *Thorn* pulled steadily westward, their speed climbing the whole time under Jupiter's fierce winds. It was therefore a little disturbing to discover a heat signature steadily increasing in definition on their aft screen. Somehow one of the other boats had managed to catch a better wind cell than theirs.

Louella jibed to port, hoping to create a pocket of dirty air behind *Thorn* that would interfere with the other's progress. The white dot responded by immediately moving to starboard, long before they could have felt the effects of Louella's maneuver.

"Obviously they can see us better than we can see them," Pascal cursed as he tried to crank up the gain. "It's probably the wind blowing our signature backwards. Should we jibe again?"

Louella dismissed the idea; *Thorn*

lost some momentum each time they jibed. "Let's concentrate on building up our speed," she replied, making some tiny adjustments to the set of the sails.

The image of the other boat faded to port and finally disappeared. They were six hours out from the start.

"What are they doing now?" Louella wondered aloud. "Could they have caught another favorable wind cell? Do you think they're starting their northward leg already?"

Pascal checked the inertial. *Thorn* was still a few hours from their planned turning point. "Let them go," he said. "Concentrate on our own course while I grab some sleep."

Pascal was having difficulty staying awake during his shift at the wheel. The days of five hour sleep cycles, bland food, and lack of exercise were taking their toll. On most of the long races on Earth he at least could stand on the deck, stretch, and get a breath of air to refresh himself. Down here, in Jupiter's atmosphere, he couldn't even stand upright, much less sniff the air blowing by outside the boat. Not that he'd want to, he hastily amended.

But it was dry, as Louella had said, and that was something. He recalled how he'd always hated the pervasive dampness, the clinging, sticky moisture that characterized every ocean race.

Thorn's trim felt wrong, as if she was lumbering in thick syrup, even though her speed was good. Perhaps, he thought, the boat would have a better feel if she rode a little higher, a

little lighter.

He clicked on the heaters in the ballast hold. They had pumped nearly four tons of liquefied gas from the bottom of the keel into the ballast tank to set their present trim. The heaters would expand the liquid and force the ballast out. He turned them off after an hour, when the trim felt better.

On the seventh day of their run they rounded CS-15 on their port side and watched the vivid image displayed on their radar screen until it faded back into the ambient noise. Pascal had dutifully recorded the close passage, to prove that they had indeed rounded the mark, while Louella concentrated on keeping *Thorn* a safe distance away. To do so she maneuvered the winches to switch the sails from side to side, slipping a little to slew the craft about without losing momentum.

As much as they'd like to do so, there was no time to stop, and no way to find out whether the station knew that they had passed. They'd tried the radio, but the deafening noise of atmospheric static masked any reply.

"I wish we could find out which boats have already gone by," Pascal remarked as he stowed the log and climbed wearily into his bunk. He loosened the truss and breathed a sigh of relief.

"The hell with them," Louella answered weakly in a voice that revealed that she too was getting tired. "We just have to do the best we can and hope that the rest do worse. That's what racing is all about."

"Yeah, remember the last Whit-

bread—didn't see another boat the whole race. It was like we had the whole ocean to ourselves."

"Not much fun there. What I remember is sitting dead in the water for three days while the Sun baked us to a crisp; no wind, no progress. It was only luck that we caught the edge of that storm and got a boost."

"Won the race, didn't we? Luck falls to those with the most skill," Pascal said encouragingly.

"Let's just hope it works this time as well," she said dryly. "Now get some shut-eye so you can relieve me in two hours."

The rest of her watch passed without incident as she tacked at a twenty degree angle to the head wind. The new sails that they had deployed on day five were still serviceable and were probably good for another two days at least. There was a minor fluctuation in the barometer and Louella let the keel down a few hundred meters. She nearly fell asleep at one point, she was so tired.

Louella was the first to notice how their track was consistently deviating to the south. On the last two tacks they had strayed nearly fifty kilometers west of plan.

"Unless there are some different physics out there we can't possibly be heading like the inertial shows," she remarked with a nod at the instrument when Pascal crawled up to relieve her.

Pascal looked at the readout. "This thing's supposed to be foolproof. Maybe you're misreading it?"

Louella snorted in reply. "You

check it yourself. I'm getting something to eat and then some shut-eye." She slid from the helmsman's perch, past Pascal, and into the stateroom. "See if you can figure out what's wrong."

Pascal kept an eye on the inertial throughout his shift. Sure enough, the southern legs showed the same deviation. If the machine was to be believed, then the winds were coming almost directly down from the north instead of following the westerly course that they had been told to expect.

He wished that he was thinking a little more clearly. Something kept itching at the edges of thought. Something someone had warned them about. What was it? He looked at the curving southerly trace that the inertial was showing and wondered. It almost looked like a smooth curve. . . . Then he had it! A turbulence eddy must have formed along the edge. If the readout was right then they were already being drawn into its grasp. "Louella!" he shouted, "wake up! We have a bit of a problem."

Hours later the winds rocked *Thorn* from side to side as Louella fought to make way. Unlike the smooth air they had encountered thus far, the winds on the edges of the storm were rough, uneven gusts that quartered with little warning. In one stomach-wrenching instance, *Thorn* had turned completely about, while pitching nearly sixty degrees to leeward, reversing as the wind switched and slammed them in the opposite direction.

She knew that they'd lost the fore-

sail, and suspected that the aft was in tatters. There was no possibility of hoisting new ones in these rough seas. Something in the sail locker had torn loose and was smashing around. Pascal would be taking his life in his hands if he tried to go into the locker. For good or ill, they had to use whatever sail they had and hope that their skill, and no small amount of luck, would see them through.

"Can't even put out a damned sea anchor to steady her," she complained at one point. "How the hell do the sailors up here survive these storms, anyhow?"

"I think they are wise enough not to do something stupid like racing in a small boat." Pascal said dryly from the bunk where he had secured himself. "How are we doing?"

Louella checked the instruments. "As far as I can see we are straightening out our track somewhat. At least we aren't curving more."

"I hope that means we aren't getting sucked in. How big do you think this storm is?"

"No telling. I don't know how they scale these storms up here. Back home this would be called a one-million year storm, I'm certain. It's a monster!"

Another gust hit them on the side. Louella threw the switch to lower the keel, and their center of gravity, to give them some more stability. It was all that she could do.

The remnants of the aft sail blew away during Pascal's watch. The rocking of the boat stopped as it drifted with the wind. Since he now had no

control over *Thorn*, he lashed the wheel in place and crawled into the sail locker. The only way they had of restoring some measure of control to the boat was to get another sail up.

The locker was a mess. The big specialty main that Louella had ordered for the finishing run had broken loose of its restraints and had swept the mountings clean off the deck. Bits of broken metal and plastic tie-downs were everywhere. A large dent on the bulkhead showed where the big sail had struck before it finally wedged itself behind the canisters.

Pascal stumbled over the wreckage and selected one of the smaller sails. He undid the lashings, trying to maintain his balance against the pitching motion of the boat. As he worked he kept a wary eye on the huge mainsail in case it began to roll his way.

Twice the boat moved unexpectedly and threw him against the stowed sails, smashing their blunt edges into his chest and back. He knew that he'd have massive bruises to show for it.

Finally, he secured the winch to the sail head and locked the cables in place. He braced himself between the sail and the bulkhead, using the pressure of his legs to hold himself in position and began the torturous process of ratcheting the sail into place. It took all of his energy to move it the last few centimeters.

Louella was awake and in the helmsman's seat when he poked his head out of the tube. "Sail ready?" she asked calmly, as if nothing was amiss.

Pascal nodded. "Aft mast, small set," he said quickly, thankful that she had not made an issue of his reckless ac-

tions. She was all cool control and professional when the race was on.

"Brace yourself," she warned as she reached for the controls. "Release!" She threw the hoist switches to raise the sail as Pascal tightened the straps to hold him in the bunk.

Louella spun the wheel to bring the boat directly into the wind. The wind caught the edge of the new sail and pulled it the rest of the way out.

Louella adjusted the traveler. The wind filled the sail, throwing *Thorn* at a sharp angle. The boat heeled precariously and then leaped forward with a force that snapped Louella's head back against the headrest. She managed the trim of the sail, a matter more of feel than science, until the boat was riding steadily downwind, making steady progress. *Thorn* rode safely and secure in the teeth of the storm.

"That's the right thing to do," she said softly to the exhausted Pascal. "Good going, partner."

The relative calm following the storm was a blessing. Rams had managed to be blown only a couple hundred kilometers south of his planned track through a combination of his skill and considerable luck. All he had to do now was intercept the CS-42 track and pray that the storm hadn't forced her too far from the projected track in his computer.

Rams checked the sail one more time and then prepared to come about. It was time to head on a northerly leg. He buckled himself to the deck and released the hold-downs on the wheel. He felt a throb rever-

berate though the deck as the rudder cut into the dense soup, far below. He imagined it to be *Primrose's* heart-beat.

The hull began to sound a deep resonant note that echoed throughout the ship. "Damn harmonics," Rams swore. He retracted the keel until the sound disappeared. Left alone, the wind blowing across the keel would set up a destructive harmonic that could destroy the ship.

"Ready, girl," he whispered, turning the wheel ever so slightly to starboard. He put one hand on the port-side jib release and waited. *Primrose* rolled to the perpendicular and then shook as her prow came through the eye of the wind.

Rams hit the port-side release and switched on the starboard-side jib winch. In his mind's eye he could see the mainsail whipping across the deck, slamming the traveler to rest on the opposite side as it turned its port side to weather.

There was a clatter of chain against the pressure hull that stopped when the loose jib finally stretched taut. *Primrose* heeled and started to pick up speed on the downwind leg. Rams held the wheel loosely, searching for balance until he was confident that the ship had once more found her line. Only then did he lock the wheel into place and relax.

He unbuckled the restraints and started to pour the last cup of tea from his thermos when he stopped. Something was out of the ordinary, but he couldn't put his finger on it. Rams examined the instrument panel. Everything seemed to be in order; no

red warning lights that would scream that the hull had been breached, no flashing indication that the rigging was damaged, no alarm telling him that some life-threatening life support system was malfunctioning. What could it have been?

Then the infrared display flashed again. Rams started in surprise. There, on the screen, was a white blob—a heat indication where there should be nothing but empty sky. A glance at the camera indicator told him that the blob was off his starboard bow, just at the edge of the imager's range.

Quickly he released the wheel and spun *Primrose* about, pulling the jib tight and letting it backwind, just as Jake had taught him. The winds buffeted the ship for a few seconds, rocking it from side to side until, finally, the motion subsided. The ship was close-hauled into the wind, the pressure on the reversed jib equal to the pressure on the loose main, and both constrained by the kilometers of keel beneath him.

He carefully turned the aft camera around, trying to find another indication of that heat signature. Several times he thought that he had it, but was mistaken. Stare at a screen of random noise long enough and you are likely to see anything you want. He continued to search.

Then he had it. A definite heat source, and quite close too. The object was moving at about the same speed and direction as the wind.

They were so far off their planned track by watch change that neither of them could see how they could make

up the lost time. "I don't see how the other competitors could have avoided the storm," Pascal remarked as he examined the charts and the trace on the inertial. "Surely they're in as bad shape as we are."

"Don't count on it," Louella snarled. "Most of them are tough sons of a bitch. Somebody probably figured out how to use this storm's winds to their advantage. I wouldn't be surprised to find that at least two of them have a good day's advantage on us."

"Oh, when did you become such an optimist?" Pascal asked bitterly.

"When I got you as a partner," she snapped back.

Pascal checked the trim while Louella snored in her bunk. *Thorn* felt sluggish—probably Louella had taken on more ballast, he thought. He switched on the heater to vent some of it and lighten the boat.

A sudden gust blew *Thorn* to the side. She tilted nearly forty degrees as the wheel whipped from side to side.

"What the hell?" Louella yelled from her bunk.

"I think the sail's gone again," Pascal yelled down at her. "Take the wheel while I get another one ready."

Louella squirmed into the seat as Pascal dragged himself into the sail locker. *Thorn* was rocking steadily from side to side. She turned on the winch to let out more keel and steady the boat, letting out another hundred meters of mesh.

"Let's try the foresail this time," she yelled at Pascal's disappearing feet.

Pascal wiggled into the cramped space beside the sails and braced him-

self. He ached all over. No matter how he positioned himself, some bruised part of his body pressed painfully against something. He rigged the lines and gear until the red-tagged foresail was ready to be ratcheted into the loading compartment.

He carefully attached the pulley to the head end of the sail and began to crank it into place. With every turn of the winch his muscles ached. He banged his elbow on the bulkhead with each long stroke of the winch handle.

With a twenty-to-one ratio, it took a long time to finally get the sail into place—long enough for the forgotten heater to turn the entire ballast load into steam.

Back in the cabin Louella noticed the sideways motion of the boat. She immediately checked the pressure gauges, thinking the wind had switched unexpectedly. But that wasn't the problem; their heading was still good and the wind had settled down. Why then were they slipping sideways? She tried to clear her head and reason it out. She wished that she weren't so damn tired.

Then she noticed the blinking warning light above the heater switch. "Damn," she swore, "how did I miss that?" and turned it off.

Pascal stuck his head out of the end of the tube. "Sail's all ready to go."

"Right, brace yourself," she responded and hit the winches to raise the sail.

Before she could react the ship moved violently to one side, throwing her from the seat and smashing her against the bulkhead. She didn't even

have time to scream.

Pascal came painfully to full consciousness. His head throbbed and his side was a mass of agony, as if his ribs had been crushed. The first thing that he saw was Louella slumped against the bulkhead of the cockpit, her arm at an awkward angle. "She must have forgotten to buckle herself in," he mumbled and crawled to her. The pain in his side stabbed each time he moved.

Louella's pulse was all right, but her breathing was labored. He turned her to one side to relieve the front-to-back pressure from the two-g gravity. She moaned as he shifted her.

He ran his hand down her arm, feeling for a break, a dislocated joint. The arm was all right, but there was a swelling at her wrist indicating a possible sprain or fracture. Since there was nothing more serious apparent, he climbed into the seat and buckled himself in. He could take care of Louella's medical problems later, after he found out what *Thorn*'s situation was. The boat always came first!

A quick glance at the instruments showed that there was no pressure differential on the sails. The wind speed indicator read a fat zero, which meant that *Thorn* must be moving at the same speed as the wind. He noted that the ballast was zip. In an obvious contradiction, the pressure gauge showed them to still be on the boundary layer. Nevertheless *Thorn* was bobbing uncomfortably, as if she had lost some trim.

He clicked on the pumps that would bring more ballast up through

the pipes. Once the boat had the proper trim he could turn her back into the wind. As he was waiting for that, he looked at the inertial. According to the readout they had lost most of their progress for the last day, at least. They were being blown back toward CS-15, but on a southward angle.

Since it would be a while until the pumps did their work he got the first-aid kit out of storage and put a splint on Louella's arm. He prepared a dose of painkiller for when she awoke. He'd only give it if she asked for it. Carefully he turned her head and waved a broken ampule under her nose.

"Wha . . . where . . . humph," she said and tried to sit up. "Wha . . . what happened?" she asked.

"Don't know. Was coming back down the tube when all hell broke loose. Threw me against the side and knocked me out. We're way off course now."

"Oh, your head," she said and reached out with her good hand to touch his forehead. "You're bleeding!"

He brushed her hand away. "Just a bump, I think—rotten headache, though. How do you feel? Do you need this?" he held up the dose he'd prepared.

"Can't take something that will knock me out. Help me get to the bunk so I can lay down. We need to figure out what we have to do. Maybe then I'll let you use it."

By the time he'd wrestled her into the bunk and fastened the straps to secure her in place, the pumps had been running for a good ten minutes.

He dropped into the seat and checked the gauges. The stabbing pains in his side abated for a moment.

"That's strange," he remarked as he flicked the pump switches on and off. "There doesn't seem to be any ballast."

"Yeah," Louella said. "You left the heaters on. I flipped them off while you were messing with the sail."

"Shit, I forgot about them when the sail blew. But that doesn't explain why the pumps aren't working."

"Maybe we're floating too high. Maybe the keel isn't deep enough to find anything to pump."

"Can't be. Pressure gauge says we're right where we're supposed to be." He glanced at the keelometer. "The keel's down as far as it will go, so we should be pumping ballast. Since we aren't that means that either the pumps have stopped working or something has damaged the lines leading to the ballast tanks."

"Either way we can't trim the boat," Louella mused. "Well, let's try using the sails anyway to see what sort of maneuverability we have. We have to be able to make one of the stations or we're royally screwed."

Pascal threw the switches to pull the foresail back from its fully extended position. As the winches brought the sail tight, *Thorn* heeled to lee instead of turning into the wind. He let the sail out, hoping to run downwind instead. Perhaps on that setting he'd be able to steer from side to side. But the boat wouldn't turn that way either.

"Unless you can think of any other things to try," he said after an hour of

experimenting with various settings of sails and the immobile keel, "I think we're stuck. There aren't any rescue boats out here. It looks like you'll get your wish to 'sail Jupiter's seas forever.' According to my calculations, *Thorn* won't intersect a station's track for at least a thousand years."

"Well, Pascal," Louella said in a surprisingly soft voice, "If we're going to die, I can't think of anybody I'd rather do it with than you, and no better place than on a racing boat."

"I'm afraid that I can," he replied too quickly and watched the gray nothingness of the infrared display as he contemplated his own death.

At least he'd be free of this damn headache, he thought.

Rams was puzzled as he approached the strangely warm object that had suddenly appeared. *Primrose* was now matched to the speed of the object. He carefully headed downwind and slowly closed the gap between them. Rams kept one hand on the winch controls as he maneuvered the ship closer and closer to the object, tightening and loosening the sail controls to creep forward.

At a few hundred meters the infrared image resolved into a strange double blob. The large upper blob was one or two hundred meters above *Primrose*. The smaller one was about the same distance below. A barely discernible thin line, apparently just a few degrees above the ambient temperature, connected the two blobs. He'd never seen anything so strange in all of the time he'd spent on

Jupiter's seas.

As he drew closer, the upper blob resolved itself into the familiar heat signature of a small craft, possibly a cargo barque or maybe a miner. Maybe the connecting line was its keel, he thought. But what was the blob at the bottom? It was far too large and irregular to be keel weights.

He pumped a little more ballast into *Primrose's* tanks and sank lower. He wasn't going to get any closer to the pair until he figured out what was going on. "Hate to mess up some science folks, wouldn't we?" he remarked to *Primrose*.

The heat image resolved into two keel ribbons. They appeared to be tangled around some large shape that was *below* ambient temperature, as if it had come from deeper in the atmosphere. He flooded it with his sonar, watching as the display built up a ghostly image of the irregular shape.

On a hunch he pinged it with the docking sonar frequency and listened through the static for the reply: One, two, three pings came back, which indicated that he had made the lump ring. Either it was hollow, which made no sense, or it had a high metallic content. Somehow the other ship had been hit by a piece of rock brought up by the storm—a huge piece that could be worth a fortune.

He brought the ship back up until it was level with the other ship, carefully staying downwind to avoid smashing into her. With fine adjustments of the jib he allowed the other ship to come closer and closer until they almost kissed.

"Hello," he yelled over the radio

link, hoping that they were close enough to overcome the static. "This is the clipper *Primrose*, four days out of CS-15. Do you need assistance?"

Louella started at the sudden and unexpected sound of a strange human voice coming over the static of the radio. Pascal tried to sit upright and looked around. Since the accident he had slept in the helmsman's seat, letting Louella have the more comfortable bunk where she could sleep. She'd relented after the second day and let him administer the painkiller. "Just make sure it isn't a lethal dose," she'd jokingly remarked. "I don't want to miss the end of this race."

"Nor I," Pascal had replied slowly, and thought about what she had just said. He'd never considered that possibility. An "accidental" mistake in dosage would certainly be something to think about as the air grew closer.

To pass the time they'd talked about things that they never seemed to have time to discuss earlier. Except for the long trip out from Earth, when she was still pissed after their big argument and wouldn't talk to him, the only time they'd had together was during the races, or while preparing for them. Under those circumstances it had been all business; winning the race, discussing the set of the sails, the movement of the currents and the wind, talking about the positions and strategies of their competition, and the endless details of reconciling her art of sailing with his science. After every race they went their separate ways, until the next race, the next challenge that threw them together.

"Always wanted to have a place on Chesapeake Bay," Louella confided during one of the times they were both awake. Since the accident they had abandoned their five hours on, five hours off schedule. "Some little marina where I could teach kids to race. Maybe have a dinghy school of my own. You know, take a shot at producing a batch of Olympic champions."

Pascal snorted at that: if he ever got out of this he wanted to live as far from the ocean as possible, maybe in Arizona or New Mexico. Someplace where wet clothing, must and mildew, and cold, sodden food were unheard of. Someplace where the damned footing was solid and the horizon always stayed level with your eyes. He yearned for some place that was dry, flat, and had no dangerous cliffs.

But neither could convince the other of the desirability of their dreams, even though the chances of achieving them were impossible. There was only a day or two left of the life support system. The water had gone the day before. Both knew that they were doomed. They would become a Jovian version of the Flying Dutchman.

"I repeat, do . . . **crackle** . . . hisssss . . . need assistance?" the voice rattled from the speaker. Pascal fumbled around under the instrument panel and found the microphone.

"I hear you loud and clear," he yelled. "Thank God you found us. I mean, yes, yes we need help badly!"

"Are . . . **crackle** pop** . . . under sail?" the voice said with what sounded like a tone of impatience.

"No," Pascal said in response. "We cannot maneuver. We are without ballast and cannot control our craft."

"**Pop. . . ** . . . wish to . . ." came the hissing reply. "Do you . . . **** . . . rescued?"

"Of course we do, you fucking idiot!" Louella screamed into the microphone. "Of course we want to be rescued!" Tears of happiness were steaming down her face even as she cursed the stupidity of the question.

"Tell him to give us instructions," Pascal said, wiping the moisture from his own face with one hand while he gently wiped at the tears on Louella's with the other as they hugged in the cramped cockpit.

Rams tried to understand what the woman was saying about the condition of their boat. The radio handled low frequencies better than high, and that made her voice difficult to understand. If only she'd stop and let the other guy talk!

"**** . . . Can't maneuver . . .," she told him: "No food, no water, . . . life support gone. We're afraid . . . **crackle** . . . ship . . . complete loss . . . abandon . . . **pop** . . ."

Rams wondered what sort of idiots they were to talk about abandoning their ship. Didn't they know the wealth that they'd discovered? Didn't they realize how valuable their own ship was? "I'll take her under tow if you want."

"Understand. **** . . . need medical . . . **tention."

"All right. I will bring you aboard and secure your ship. By the way," he said slyly, "will you give me salvage

rights if I do so?"

It took him several repeats before he could make them understand just what he was asking. He made sure that he had their request to abandon ship on file. It had to be clear that it was their idea, not a threat by him. He really had no choice but to help them—that was how you survived on Jupiter.

Rams struggled into the heavy pressure suit and, once inside, hooked its safety line to the ring near the hatch. Attached to his belt were lengths of high tensile strength line. He could use them to string the two craft together. Checking to make certain that everything was ready, he opened the hatch and stepped directly out into the howling winds of Jupiter.

Rams had brought the far larger *Primrose* to within fifty meters of the smaller ship's hull, letting the venturi effect of the winds in the narrow channel hold them close.

His exterior lights just barely illuminated the upper surface of the other ship. Rams watched as two figures struggled awkwardly out of the hatch and clamped their lines onto the deck rings.

The two ships bucked and lurched, the gap between them widening and closing. The decks rose and sank relative to each other as they bobbed, side by side. Rams prayed that he'd set the ship's sails properly to hold station with the drifting ship. He clicked his suit light four times to attract their attention.

When he got a wave of acknowledgement, he readied one of the lines, whirling the pulley at its end over his

head in ever widening circles before releasing it upwind. The pulley sailed out and too quickly down, drawn by the higher acceleration of Jupiter's gravity. It clanked onto the near side of *Thorn's* hull and slipped away.

Rams retrieved the line and tried again, and a third time. On the fourth toss, the pulley finally cleared the deck. The line whipped around to catch against the two figures, making the smaller of them stagger back from the impact.

The other figure secured the pulley to their deck with one arm and waited. Rams carefully pulled the light line back as he paid out a heavier one that was tied to its end. It took nearly half an hour before he had a slack double line rigged between the two rocking and bobbing craft. The line moved up and down, tightening and then loosening as the two ships lurched in the wind. He wrapped the line around a deck winch and locked it in place.

Finally, Rams attached a cradle of ropes and clamps he had rigged to a hook on the heavier line. Slowly he winched the cradle to the other ship, hoping that they would use it properly. The last thing he wanted was for someone to take a plunge.

"You first," Pascal said nervously as he caught hold of the rig. "Let me hook you up."

"No fucking way. I'm the captain of this boat and I leave last," Louella replied. "Turn around so I can hook the clamps to your suit."

"Yeah, and how are you going to hook yourself up with a broken arm?" he shot back. "Now turn around. For

once, don't be such a bitch!"

"Why, Pascal," she said in surprise. "That sounds like you actually care about me."

"Well, it looks like we'll have the Whitbread next year after all," he said as he checked the rig's fastenings a second time to make certain they were secure. "I wouldn't want to be with anyone else in that race."

"It's a date, lover," said Louella.

Once he saw that Louella had been dipped, jerked, and lurched to the other ship, Pascal had to face what would happen next. In a few moments the rig would return and he would have to hook himself to it so that his rescuer could winch him across the bottomless chasm of Jupiter's atmosphere. Instead of a nice solid deck beneath his feet there would be nothing but black nothingness that went down forever, down into the cold heart of this cruel planet. He'd be suspended by only a few thin filaments of braided cord and his trust in the skill of some unknown captain. For long minutes he would be swinging above the great void, helpless as the strong fingers of Jupiter drew him down, down, down.

He doubted that he really had the nerve. Could he really trust himself to that hopelessly thin cable? And even if he did, where would he then find the courage to step out, off the solid deck, and place himself at risk?

The moment of decision had come. The rig was swinging out of the bright lights of the other ship and coming toward him. His stomach hurt. He was either going to die on this crippled

ship or drop to a certain death. He felt like crying, he was so afraid.

"What are you doing out here anyway?" Rams asked as he unhooked the woman from the rig, confident that the suit radios would work at this close range. "You sure don't look like miners."

"We're one of the teams in the Great Race," Louella replied.

"A race? On Jupiter? What sort of foolishness is that?"

"Don't tell me that you haven't heard about the Race. Hell, it's been on every newscast for the last year. Crap, we're probably the biggest celebrities on the whole planet."

"Don't have much time for news," Rams replied. "Radio don't work down here. Have to depend on the media they send down the elevator to keep up with events. Besides, if it doesn't have to do with cargo or weather I don't pay much attention to it."

"We're in a race with some other barkentines—it's the first Jupiter sailboat race," Louella explained. "JBI sponsored and financed our boat."

Rams cursed softly to himself, and then said aloud, "Must be nice to be able to waste money like that. I can think of guys who could use that boat for something worthwhile; something better than some fancy trophy!" he added vehemently.

"Well, I'm certain that JBI will be grateful. They'll probably reward you for rescuing us."

"Well, that might be nice, but I'm going to get more than a little reward out of JBI, you can depend on that. Sal-

vage alone ought to pay off the debt on *Primrose*—that's my ship," he added pointing at the deck with one glove. "The other thing might pay for something more."

"What other thing?" Louella asked, but Rams ignored her.

"What's going on with your partner?" he wondered. "What the devil is he waiting for? Why isn't he hooking himself up to the rig?"

"I was afraid this would happen," Louella answered. "Pascal's afraid of heights. Probably shitting in his suit right now, just thinking about the drop in front of him." Louella waved her good arm vigorously over her head. "Come on Pascal, you asshole; hook up and get the hell over here!" she shouted, forgetting that the object of her scorn couldn't possibly hear her.

After long minutes of waiting with no sign of action by the small figure on the deck of *Thorn*, Rams swore. "Do you think that you can operate that winch with one hand? Looks like I need to go over there and kick your buddy in the ass."

When Louella signaled the affirmative, Rams connected a pair of heavy lines to his belt. One of them was tied to the stern docking ring. He activated the winch to bring the rig back.

He grabbed the rig as it swung back, hooked it to the rings of his suit, and signaled Louella to start the winch. "Keep those lines from tangling," he warned her as he stepped off the deck and began to swing across the gap.

As soon as Rams's boots hit *Thorn*'s deck, he secured his safety line. He detached the rig and quickly clamped

it to Pascal's suit, brushing aside the other man's arms when Pascal fought him. He secured the last clamp, unclipped Pascal's safety line, and waved his arm for Louella to start the winch.

Pascal protested, stiff-legged, against the pull of the winch. The resistance was putting an extra load on the line, so Rams stiff-armed him in the middle of the back, forcing him forward. At that moment the two ships spread apart and pulled the line taut. With a scream, Pascal was yanked from the deck to hang above the inky blackness. As the ships bobbed and danced in the winds, he jerked on the line like a spastic marionette.

Rams headed aft to secure one of the heavy lines to the stern docking ring. The other end was tied to the docking winch on *Primrose* and could be used to pull *Thorn*.

After tying the line Rams dropped through the hatch and recovered *Thorn*'s log. The owners would probably want it if they couldn't get the ship back. He stowed the log in his hip pouch and emerged on deck just in time to catch the returning rig. He grabbed it and lashed it to the deck. It would stay until he was finished securing the other line to the bow.

Thorn lurched, dropping far below *Primrose*. She rocked violently from side to side, her motion the result of the enormous mass embedded in her keel. If that thin ribbon broke from the strain, it would release the weight, and *Thorn* would shoot up like a released cork, endangering both ships.

Quickly paying the safety line behind him, Rams struggled to the bow.

Bracing himself against further moves of the deck, he clamped the second line to the ring. This way, after he connected the other end of this lead line to *Primrose's* forward winch, he could adjust the two ships so they rode side by side.

Satisfied with his work, he took the free end and began his way back to the rig. When he managed a quick glance at *Primrose*, he noticed that her sails were shifting, which indicated that she might be drifting, changing her heading. He had to get back and trim her sails before she got out of control. He started walking faster.

He was halfway back when a sudden gust shot the two ships apart. The tow line he'd tied at the stern straightened and vibrated like a violin string. The safety line parted with a snap that whipped the rig out and back. In seconds it was flailing downwind, lashing the hide of *Thorn* like the whip of a deranged jockey.

Rams straightened as the *Thorn's* bow swung away and the ship came stern-wise to *Primrose*, where it jolted it to a stop. He stumbled backwards, trying to regain his balance, just as the wishbone switched sides and slammed to the end of the extended traveler.

And against Rams's right leg.

The intense pain in his leg was the first thing Rams felt when he recovered consciousness. Then he tried to make sense of the upside down view of the swaying side of the ship. He realized that he was hanging head down from his safety line, his left leg bent under him. First, he felt cold, and then hot as the pain from his leg shot

through him. Waves of increasingly severe pain washed up from his leg until he could think of nothing else.

During a brief respite from the pain, he tried to move. Something was holding his arm immobile. He tried to reach across with the other arm, desperately seeking the safety line that lay somewhere out of sight. After a few fumbling tries he gave up. Hell, even if he could find it, he wouldn't be able to climb back to the deck, not in his condition.

He calmly assessed his situation before the pain returned. He obviously couldn't do anything for himself, and the only other help was a woman with a broken arm and a little fart who was too afraid to do anything. Neither one would be able to help him. He was going to die.

Without warning he lost his dinner, fouling the inside of his helmet and filling his nose with sour, burning fluid.

Then he passed out.

Pascal picked himself off of the deck and looked toward *Thorn*. She was gone! In a panic he looked to the other side, saw nothing, and then looked to the stern.

Very faintly he could see the dim reflection of the ship's lights off *Thorn's* pointed stern. Glinting in the lights was the thin line that held the two together; it must be the line the captain had rigged before the wind hit them.

"Do you see him?" Louella's voice crackled in his ears. "I lost sight of him when the gust hit us."

"Was he blown away? I don't see the safety line he rigged."

"It broke when we separated. Do

you think he fell?" Louella screamed.

A wave of nausea washed through Pascal; his worst nightmare: to fall endlessly into the heavy, empty blackness beneath them. That could have been him if the line had separated when he was coming across. Thank God he was safely tied to this deck when it happened, he thought.

Louella was pulling on his arm, pointing toward the hatch. He followed quickly, eager for the added security of the ship.

"I've got to bring the two ships alongside, so we can bring him back," were the first words he heard when he undid his helmet in the small air lock. "We've got to get the ships positioned like they were."

Pascal nodded his head in agreement. If they could turn this huge ship so that *Thorn* was once again flying alongside, they could toss another line across and pull the captain back to safety. He bit his lip; it would be hard, going out on deck again, but he felt that he could do it.

"I'll ready a new line," he said, and screwed his helmet and his courage into place.

Louella couldn't possibly toss the line across with only one good arm. On the other hand, he had no doubt of her ability to handle this, or any other ship, even with one arm in a sling.

None whatsoever.

Through the most disconcerting lurches and jumps, Louella managed to bring *Thorn* back alongside. *Primrose* was actually sailing backwards, the wind on the reverse of her sails.

This allowed her to drag *Thorn* by the single tow line back into the range of *Primrose's* bright lights.

Pascal was dismayed when he saw the dangling figure of their rescuer. He waved furiously, hoping the captain would wave back. But his attempt was in vain—the far figure dangled lifelessly, swinging from side to side with every motion of the boat.

Pascal pondered his situation. How was he to get a safety line across if the other man couldn't secure it? He didn't know whether the captain was dead or alive, awake or unconscious. But he couldn't just leave him there, alone in the dark, waiting to fall should that single, thin thread holding him in place break. What could he do?

He looked at the flapping remains of the former safety line whipping back and forth against the side of the boat, somehow hoping to find it restored.

Louella certainly wouldn't be able to help, not with her arm out of commission. He stood there for long minutes as he considered his options. First, Rams might recover and climb back up to where he could catch a line. That would allow him to winch the captain back.

If that didn't happen then he could, he could . . . what? Leap across the space between the ships, pick Rams up in his arms and leap back? Pascal watched the motions of the two ships carefully as they rose and fell, closed and separated, shifted forward and back, the one with a little sideways motion and the other rolling precariously. Jumping would be impossible, not only because of the unpredictable

movement of the ships but for the distance as well. He'd barely clear the edge of the deck before plunging down. . . . He let the thought stop there as he tightened his sphincters. He discarded that option quickly.

Maybe, he hoped, he could catch the line on something over there and pull Rams back. Four futile tries showed him the stupidity of that idea. Which left only one option—going over to the other ship and bringing the slumped figure to safety. But how? He certainly couldn't get near the edge and risk that long, long fall beneath them.

He went back to the hatch, where he plugged into the intercom and explained the situation to Louella. Surely she would understand, he thought.

"You're wasting time thinking about it, damn it! Get your ass over there and get him back!" Louella screamed. "I don't give a rat's ass how you feel; if you don't get started in ten minutes I'll make sure that it gets done myself."

The thought of Louella with her arm in a cast trying to rescue Rams was so ludicrous that Pascal began to laugh. "You couldn't even get your suit on by yourself," he wheezed.

"Exactly, but one hand is all I need to lock the damn hatch so you can't get back in without him."

Pascal was horrified, doubting her at first, and then realizing that she was entirely capable of carrying out her threat. "You wouldn't," he said.

"Just try me," she shot back.

Pascal climbed back on deck and winched the stern tow line as close as was safe. He thought that he could

slide down the line, but then realized that he couldn't chance it—one slip and he'd drop into the ten or fifteen meter gap between the ships and plunge into the forever, below. What if he froze halfway across? He'd probably hang there until he gave in to vertigo and then he'd fall, fall, fall into the black maw that thirsted, that called out to him. He shook his head and stepped back farther from the edge of the deck. How could he overcome this fear that left him incapable of action? There had to be some other way, some way to rescue Rams without having to risk a fall. There had to be!

He returned to the hatch and pleaded with Louella to think of something, some way that did not involve making him cross the deep chasm of his innermost fear. They reached the same conclusion as before; that he was the sole resource they had to save Rams.

"In case you think I was kidding, I've already locked the hatch," she muttered before cutting off the conversation.

Pascal debated testing the hatch to see if she had really carried out her threat, but decided against it. He really didn't care to find out.

He returned topside and worked his way carefully to the stern. He stood there and contemplated what he had to do; what he could not escape doing, no matter what his fear.

Louella had been doing a good job of keeping station. *Thorn* was still drifting off to the port side, slightly below *Primrose's* level. Their positions gave the tow line a downward slope.

All that he had to do was tie himself to the line and slide down to *Thorn's*

deck. It sounded so easy, so terribly easy. But what if the line parted? No, he couldn't afford to think about that.

Pascal retreated to the winch at midships, tore the remnants of the safety line away and wrapped a new line, fastening the other end to his suit. *That* would give him some added security, and could be used to drag Rams back aboard.

He fashioned a short loop around the tow rope with a short length of line, and tied both ends to his suit. After a moment's hesitation, he attached a second loop—and a third. Just for safety's sake, he detached the line that held him to the deck and put that around the tow as well. Finally certain that he was quadruple redundantly safe, he lay under the tow and grasped the line with both hands.

Through the narrow visor of his helmet he could only see the tow rope and the spider's web of lines he had attached. He concentrated on the line and his gloves around it, trying to suppress any thoughts of what he was about to do. He tried to drive away all thoughts of the depths below him, drawing him so deathly down, down, down. . . .

Pascal shook himself. If he hesitated for one more second, thinking about it, he would be unable to move. Ignoring a shudder of stomach-wrenching fear that tore at his insides, he tugged at the tow with one hand, said a short prayer, and began to slide.

There was a snap, a millisecond of a fall, as the slack in his safety lines was taken up by his weight. The tow vibrated for a second more and then Pascal was falling, sliding, hitting the

deck of *Thorn* with a bone-jarring impact. He clutched the tow tightly through his gloves as he tested the solid reality of the deck beneath his feet. He had made it, he had not fallen. He had conquered the depths of his fear. Nothing was beyond him now. Nothing!

The smell inside his suit told him that his body had not shared his courage.

Squirring around to pull himself upright, securing a new safety line to the rolling deck, untangling the many lines that held him to the tow line, and making his way forward to stand on the deck above Rams took only a few minutes. The captain was still hanging, just a few meters down the side. Pascal could see that he had the safety line wrapped around one arm, pinning it to his side.

"Captain?" he called when he thought he was within range of the other's radio. "Can you hear me?" Only silence answered him. He could expect no help from Rams.

But how was he to get Rams's unconscious body up on deck? It would be impossible to pull the man the short distance up the side with the safety line. At best, he couldn't lift his own weight under two gs. What chance did he have of pulling a larger man, and one enclosed in a heavy pressure suit, that far? It would be the equivalent of lifting 350 kilos on Earth! Even professional weightlifters had trouble with that kind of load. No, he couldn't do that.

Neither did he think he could maneuver the tangled safety line sideways to the winch and use that to pull

him up. A lateral pull would be the same as lifting Rams a half a meter or more, out of the question.

There was no choice; he'd have to climb down and attach the safety line he'd brought with him. Easy to say—sure, just drop down and hang over the depths once again. Nothing to it, he told himself. After all, hadn't he come across the gap?

No, *you can't*, his mind replied as the edges of his innermost fear crept back in. He tried not to listen to it as he rigged two lines to the deck; one to support him and one more for additional security. His empty stomach clenched in a knot of sour fear the whole time. He fervently wished that he didn't have to do this, that there was some other way. Tears stung his eyes. The fear of falling was too great to bear. Why did it have to be him?

The line he'd tied to the *Primrose's* winch was attached to his belt, ready to clamp onto Rams's suit. Not incidentally, it provided another layer of security for himself.

Screwing up all of the resolve he could muster, he turned his back on *Primrose* and forced himself to take one small step backwards, out and down, paying a few centimeters of line out behind him. He froze. He could move no farther no matter how hard he forced his legs to move. His fear had taken control. He couldn't put himself in danger.

Thorn suddenly started to roll to starboard and Pascal watched the level deck in front of him start to tilt away. He rapidly stepped backwards, trying to stay on the top of the rolling ship, letting out line as fast as he could.

Then, as *Thorn* heeled to a sixty degree list, Pascal found himself beside Rams. There was a solid deck directly beneath his feet. "Piece of cake," he remarked and knelt to attach the safety line to Rams.

First, though, he had to disconnect the tangled line. The tension between that and the safety line to *Primrose* would break the captain's arm if he didn't. He freed the line and let the wind take it.

He disconnected the safety line from his suit to clip it to Rams's when *Thorn* began to roll the other way. Rams's body started to slide down the hull. Pascal extended the safety clamp but was stopped short by the limits of the other line. The ship continued to roll. The captain was sliding. In seconds he would plunge into the dark and fall.

Pascal fumbled to release his own line, trying to balance on the moving hull. His fingers didn't want to operate the clamp. He felt himself starting to slide on the steepening slope. With a final, desperate twist of his hand, Pascal released the restricting line, lunged forward, and clipped the clamp onto Rams's suit.

Both of them began to slide, faster and faster, down the increasingly steep side of the ship. In a panic Pascal threw both arms and one leg around Rams's body, clinging to him in desperation, as the hull beneath him changed to a vertical wall.

Pascal screamed in pure terror as he felt them fall from the ship and down into the dark. He *knew* that the thin line he had put on Rams wouldn't hold the weight of both of them. He

screamed louder as their downward fall stopped and they swung to the top of their arc and began to fall the other way.

"I am going to die. I am going to die," he repeated in an unending string of fear-crazed babble. He could feel Jupiter pulling at him, trying to pry his hands apart so he would fall, fall, fall. It was very dark and the manic strength of his arms were all that stood between him and certain death. He clenched his eyes tight and prayed as he had never prayed before.

There are moments in a man's life when he faces the core of his being; a single defining moment when his true nature is revealed to him and all pretense, all bluff and bluster, are stripped away. This was Pascal's moment. He knew that he would never be able to conquer the fear that rested in his innermost being. He knew that he was, at heart, a coward.

Something clanged on the back of Pascal's suit as they slammed against something, hard! He felt them start to swing out, and then "CLANG!"—he hit again. He opened his eyes and saw a vast gray wall receding from him. In seconds, they reached the end of their arc and the wall advanced to smash against him once more. He threw his legs out to brace and absorbed the worst of the impact. Rams nearly twisted from his grasp as they hit.

It took him a second to realize that the "wall" was actually the side of *Primrose*. It took him another second to realize that it was moving steadily downward beneath his feet.

He risked a glance up and saw the

taut line disappear around the curve of the ship. They were definitely being pulled up the side. He set his feet against the ship's side and walked up the wall, clutching tightly to Rams and frightfully aware of the depths behind him, beneath him.

As soon he came over the edge of the deck he saw Louella standing by the winch. Finally, he was to the point where he could walk more or less upright. From Louella's perspective it must look as if he were holding the unconscious form of Rams in his arms. He hoped that she wouldn't realize that he was hanging on to the man for dear life. He hoped that she had not heard him screaming in the dark.

"Secure the ship," Louella yelled as soon as the winch stopped. With shaking hands Pascal quickly clipped himself to a safety line. That done, he struggled forward to secure the heavy line to the forward docking winch. The slow progress forward and back gave him time to compose himself. Time for the acceptance of his true nature to sink in.

"Don't worry. Everything's under control," were the first words that Rams heard when he finally recovered consciousness. The pain in his leg had stopped, as had all other sensation below his waist. "We've got both ships secured and we're out of the storm."

"My legs. . . ." he began and then stopped. A woman stood over him like a welcoming angel. One of her arms was in a sling.

"Gave you a nice little spinal to hold off the pain from your broken

leg," the woman said with a chuckle. "But don't worry, you'll be functioning below the waist in a few days. At least I hope so."

"I don't understand. All I remember is getting hit from behind and. . . ."

The woman smiled. It was a nice smile, he thought. "Pascal went after you and dragged your ass back here." She grinned, "I think he'll stop shaking by the time we make station."

"But how, where, what. . . ?" Rams mumbled in confusion, feeling himself start to slip back into unconsciousness. "I thought that he was too afraid."

Louella shrugged. "I guess the sea's got a way of getting the most extraordinary things out of you."

"The sea. . . ?"

"Rest now. You've got JBI's most expensive and experienced captain and navigator looking after you. I would think we have a reasonable chance of finding a station with that combination."

"... Station," Rams thought as he succumbed to the call of the drugs. She'd said both ships were secure. He thought of the riches that awaited him.

The storms really did provide the most amazing things. ■



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G. Harry Stine

WILL THEY LET THE SPACESHIPS FLY?

To get from a science to a working technology requires a solid knowledge of physical law—but that's not enough.

In the next ten years, we will have developed the technology, favorable economics, and profitable business procedures for operating cheap, safe, reliable, on-schedule, passenger-carrying, reusable spaceships capable of daily operations to and from Low-Earth Orbit (LEO).

However, we may not be permitted to fly them!

Why?

Politicians, bureaucrats, regulators, and lawyers may not let us.

A welter of confusing treaties, international laws, international agreements, federal regulations, and other non-technical and non-economic factors now exist. Many of these were born of the Cold War when all space activities were conducted by governments. This was also a period when collectivism, communism, socialism,

and other ideologies hostile to private enterprise seemed to be the "wave of the future."

The non-technical, non-economic, and non-business hurdles also include some bureaucratic turf issues within the United States government.

Far too many authors who write contemporary science fiction about commercial space activities have overlooked these. They may consider the issues to be trivial. They are not. In the classical motion picture, *Destination Moon*, written by Robert A. Heinlein (who did understand that these issues could be critical), the launch of the Moon ship *Luna* is almost halted by the arrival of a process server bearing a legal injunction against the flight.

Unless space entrepreneurs and advocates awaken to these factors and

begin to do something to change the situation, they may not be able to travel freely to and from space. This means that effort must be directed into changing the system that now exists. In turn, it requires operating within the system, building alliances with organizations formerly considered "beyond the Pale," and working with the international and governmental agencies so that commercial space becomes a win-win game.

We must face all of the issues discussed herein. The sooner we do it, the better. Furthermore, since it is yet early in the commercial space age, we can start with a Green Field approach.

It is not the purpose of this article to suggest or propose answers but to point out problems that require answers . . . and soon.

In order to fly into space, a spaceship must depart from a location on the Earth's surface. If it is a reusable spaceship—the only kind that shows any indication of being commercially economical—it must return to a location on the ground. This site is called a "spaceport." Several dozen spaceports are likely to exist around the world a quarter-century from now. They must be thought of not as artillery ranges the way space launch facilities are today, but as special types of airports used by very high-performance space-going airplanes.

The biggest and most bothersome legal and regulatory issues relating to spaceship operations will initially involve spaceport locations and operations.

In the real world, commercial spaceships will not—repeat not—op-

erate for very long in and out of national artillery test ranges such as White Sands, Cape Canaveral, and Vandenberg Air Force Base. Although these sites are protected by huge volumes of restricted air space that might simplify operations, there are only three such sites. With their legacies as long-range missile test ranges, their safety and operational procedures amount to gross overkill for the spaceships we know we can build and operate. As some commercial spaceship companies are discovering, it's very expensive to operate on these national ranges. The overhead is high because of the old-style artillery-range manner of operation. Because of the cost and operational difficulties of using existing missile test ranges, commercial space ship operators are going to gravitate to commercial spaceports away from the existing ranges. In fact, this trend has already begun.

When discussing commercial spaceports, three general major issues need to be addressed.

The first is public safety having to do with fire, environmental, and other potential and *perceived* hazards.

The second is spaceship certification that has a bearing on the safety and reliability of the spaceships just as it does with respect to aircraft.

The third issue is airspace management. Spaceships flying to and from spaceports are going to have to share the airspace with things that are already up there flying around.

Looking at the public safety issue, we are fortunate in having some national standards already in place. Why is this important?

All rocket-powered spacecraft flights to date have taken place under government contracts on national ranges or from military bases. This has allowed local and state public safety officials to sit back and breathe a sigh of relief because such space operations are the responsibility of the federal government over which they have no jurisdiction. Therefore they have no responsibility to their state and local constituencies, including the politicians.

When someone proposes to create a commercial spaceport, one of the first hurdles they must clear is that of the "authority having jurisdiction" (AHJ) over public safety matters. The AHJ will probably be very negative because he doesn't know how to handle what are, to him, new and unknown safety issues. Fortunately, an organization called the National Fire Protection Association, a national standards setting organization, has developed more than a hundred standards documents. Many of these relate to spaceport safety issues. These include:

NFPA 43-A, Storage of Liquid and Solid Oxidizers.

NFPA 50-B, Liquefied Hydrogen Systems.

NFPA 55, Compressed and Liquefied Gases in Portable Cylinders.

They are all American National Standards Institute (ANSI) standards as well.

The Arizona Space Commission has evaluated several sites around the state for potential spaceport venues. In this process, I've talked to a number of local AHJs. The first reaction is always, "How can we make sure that

liquid oxygen and liquid hydrogen are stored and handled safely? What fire fighting procedures are necessary?" When the AHJ was told that the NFPA already had standards covering these matters, the response was, "OK, then we'll just follow the NFPA standards and make sure that the people who are doing these things conform."

Therefore, the fire marshal or department chief can give his inspectors copies of the NFPA documents and tell them to make sure the spaceport people follow those rules.

And from the viewpoint of the commercial operators, they know what they're getting into because they have copies of the codes, too. They know what to follow and what is expected of them.

This should be an example of the fact that, if people look around, they can find solutions to some of the problems out there already.

Spaceships in flight present a different set of problems.

The basic concern of most people is exemplified by the question most often asked about spaceships and commercial spaceports: "*What if these spaceships blow up and fall on our heads?*"

The public once had the same concern about airplanes. When was the last time a Boeing 737 fell on someone's head? Occasionally, an airliner will crash on takeoff or during a landing approach. It's a major story when it happens because it's rare enough to be considered hot news. American Airlines had an engine drop off a Boeing 727-200 over New Mexico several years ago, again a rare occasion. How-

ever, it isn't very often that an airplane blows up, much less lands on people. Why?

No aircraft goes into the air above the United States until and unless it has been certificated as "airworthy" by the Federal Aviation Administration. Airworthiness certification is a thorough and complex process. The details are spelled out in great and comprehensive detail in the Federal Aviation Regulations (FARs).

Several categories of aircraft certification exist.

The basic regulation is FAR Part 21 covering general, overall aircraft safety and reliability.

Part 23 applies to normal, utility, acrobatic and commuter aircraft, types considered to be "general aviation" airplanes. This is likely to change because commuter aircraft will probably be reassigned to the next category, which is FAR Part 25. This is a far more detailed certification process applying to commercial transport aircraft.

Another FAR part pertains to the airworthiness certification of rotorcraft (helicopters) and yet another one to rotorcraft used in commercial service. An FAR certification part covers manned free balloons.

The engineering details relating to airworthiness certification in the FARs are thorough. They are full of graphs and charts. They even set forth such details as the slant of the lever on the instrument panel that controls retracting and extending the landing gear. This also must have a certain, specific shape. The flap control switch has a certain, specific shape as well. So

does the mixture control, for example. All a pilot has to do is reach out and touch a control to know what it is. Often when you're driving an airplane around the sky you don't have time to look at what control your hand is touching. You have to know where it is and what it feels like. It's part of the switchology of flying airplanes.

FAA certification regulations and procedures must be adopted for spaceships. To make this happen, we need a paradigm shift.

We need to change the way people think about spaceships.

Stop thinking that spaceships are the same as the expendable rockets or the space shuttle launched from the Cape. *Think of them as high performance aircraft.*

If spaceships are designed like aircraft, built like aircraft, tested like aircraft, certificated like aircraft, operated like aircraft, and maintained like aircraft, this creates a whole new picture of commercial space flight. It's called a paradigm shift.

We must get this idea across to airport managers, public safety officials, city and state governments, the FAA, the federal agencies, and the public: The new reusable spaceships are nothing more than high performance aircraft. Yes, they happen to fly out of the atmosphere. However, they must go through the atmosphere to get where they're going and to come back from where they've been.

The FAA also has regulations pertaining to the operation of aircraft.

FAR Part 91 covers general operating rules.

FAR Part 121 has to do with how airline transport aircraft are maintained and operated.

FAR 135 applies to the maintenance and operation of commuter, charter, and air taxi aircraft.

Furthermore, the FAA issues non-regulatory but binding "Advisory Circulars." One is entitled "Maintenance Control by Reliability Methods." Another is called "Continuous Airworthiness Maintenance Programs."

If you are going to build and operate spaceships, you will have to know what is in these documents although they don't relate to spaceships at the moment. However, in the near future it is quite likely that something like them will.

In October 1995, the Office of Commercial Space Transportation (OCST), formerly a separate agency within the US Department of Transportation, was merged into the DOT's Federal Aviation Administration.

OCST was created to handle the federal government's legal responsibility under the various UN space treaties. OCST issues permits and licenses for payloads, launch vehicles, and flights. The OCST regulations were established more than ten years ago when the only commercial space operations then anticipated would be one-of-a-kind flights using expendable progeny of intercontinental ballistic missiles (long-range artillery shells). The main objective of the OCST regulations is to protect the federal government from the liability provisions of the UN space treaties.

The people at OCST realize that their regulations will have to be re-

vised to conform to the style and substance of the existing FARs. Some of the FAA regulations are quite different from those of OCST. It's going to be interesting to see how OCST and FAA manage to merge them.

One of the consequences may be "FAR Part 30." It doesn't exist now. This could cover the "airworthiness" and "spaceworthiness" certification of reusable commercial spaceships. To operate reusable spaceships as high-performance aircraft, spaceship certification must be carried out to the same level of thoroughness as the certification procedures for airline transport aircraft in the existing FARs.

The third issue is airspace management.

Spaceships coming and going from commercial spaceports will have to share the airspace with not only birds (which are certified as airworthy by a higher authority than the FAA) but also with aluminum and titanium flying machines called 747s, A-300s, and MD-11s, for example. This "big iron" also must share the air with general aviation aircraft, balloons, sailplanes, experimental aircraft, hang gliders, and other machines up there flying around. If any conflict occurs, as the euphemism goes, a real problem presents itself.

The FAA has therefore divided airspace into various categories in order to exercise safety control over what flies around where and under what conditions.

For example, Class A Airspace is everything from 18,000 feet up to 60,000 feet. All pilots must fly under instrument flight rules in that air-

space. Class B Airspace covers the airspace around such major airports as New York, Chicago, and Los Angeles. To operate in Class B Airspace, a pilot must contact Air Traffic Control by radio and get permission to enter that airspace. Other categories of airspace are less complex. In Class E Airspace, which covers most of the country, a pilot can still fly under Visual Flight Rules (VFR) without permission. Class G Airspace is uncontrolled airspace. Very little of that is left in the United States.

Spaceships will have to operate in and out and through the existing airspace structure. Can they do it? Yes, if

the rules are written or revised to consider reusable spaceships as high-performance aircraft.

Different types of spaceships must be considered. The horizontal-take-off-horizontal-landing (HTOHL) type such as the X-30 National Aerospace plane may operate very much like airplanes. Two problems exist with HTOHL. First, neither the materials or the propulsion systems presently exist to make them possible. Secondly, they will be very noisy and thus will not meet the environmental noise requirements of the FARs. The new jet airliners are very quiet because of these regulations. Most of the older

Airspace Classes

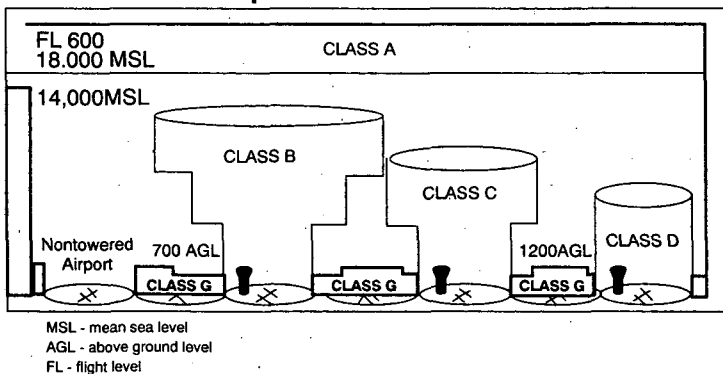


Figure 1: FAA Airspace Classes. Class A Airspace is controlled airspace between 18,000 feet MSL to flight level 600 (60,000) feet MSL. Class B Airspace is found around busy terminals such as New York and Los Angeles. Class C Airspace surrounds less-active airports while Class D Airspace is a 5-mile volume around an airport with an operating control tower. Class E Airspace is controlled between the surface and 18,000 feet MSL while Class G Airspace is uncontrolled (and scarce). There is no Class F Airspace in the USA.

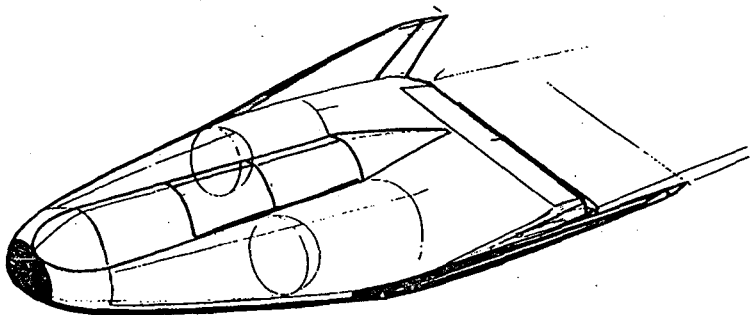


Figure 2: Sketch of the early Lockheed Martin X-33 proposal, a Vertical-Take-Off-Horizontal-Landing (VTOHL) spaceship.

jet airliners—which are perfectly good airplanes but can't meet the FAA noise limits—have been sold to Third World countries. In a place like Mali or Ethiopia, they don't care about noise as long as the airplanes can fly.

The vertical-take-off-horizontal-landing (VTOHL) spaceships proposed by Rockwell International and Lockheed-Martin as their entries in the X-33 competition also face both airspace and noise problems during the landing phase of their flights.

A horizontal lander requires an airspace approach and landing corridor that can be cleared of traffic before the spaceship de-orbits for approach. Once it starts to come home to Earth, it's like the space shuttle Orbiter. Early VTOHLs may not have powered landing or go-around capabilities. Once committed to landing by the de-orbit maneuver, it's a matter of "Here I come, ready or not!" This makes for a very messy airspace management situation because other types of aircraft will compete for the use of that air-

space or the Air Traffic Control people may not be talking to everyone flying in that airspace.

A horizontal lander also has a noise problem but it isn't caused by rocket engine exhausts. Anyone who has been to a space shuttle Orbiter landing knows the Orbiter is on approach. It announces itself by two sharp bangs: the supersonic shock wave before the Orbiter slows to subsonic speed.

Some people don't like sonic booms. The FARs decree that an airplane cannot be flown supersonically over the United States without special permission. The US Air Force and the US Navy don't have to abide by this rule in certain types of military airspace. Phoenix and Las Vegas get boomed occasionally as the sonic noise footprints extend beyond the military airspace boundaries under certain meteorological conditions.

The NASA space shuttle Orbiter is exempt from the FARs because back in the 1970s the FAA General Counsel is-

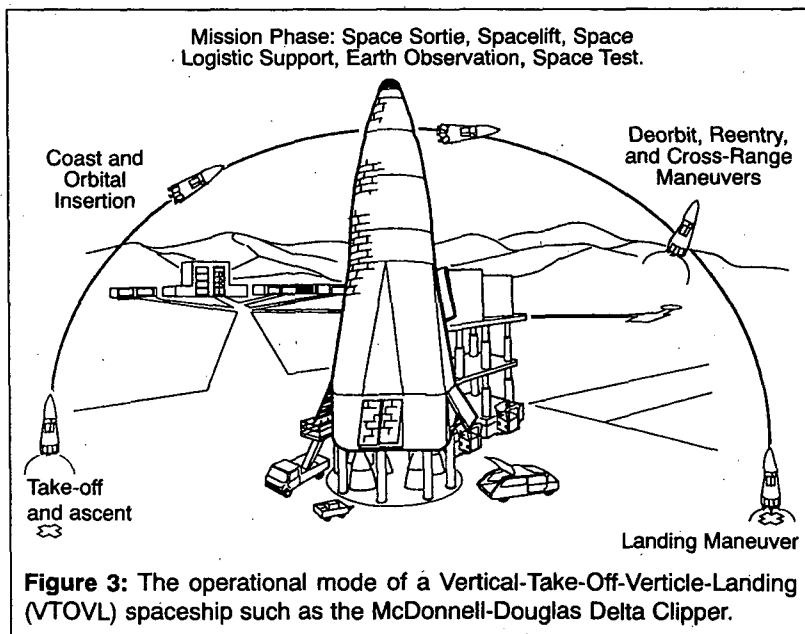
sued an opinion that the space shuttle isn't an airplane even though it approaches and lands as a manned unpowered glider. This opinion conflicts with a 1957 UN General Assembly Resolution stating that air law applies to spacecraft operating in airspace. So Orlando or Bakersfield get boomed by the Orbiter at the end of every mission.

However, when commercial spaceships begin operating out of spaceports on a daily or even hourly basis, sonic booms during the approach of a horizontal lander are going to be a different matter. People will complain although the sonic booms are expected with the arrival of the 5:15 flight every afternoon. Therefore, one of the biggest hurdles related to operating horizontal landers will be the

noise footprint and its environmental impact.

On the other hand, vertical-take-off-vertical-landing (VTOVL) spaceships can probably operate in the existing airspace mix with a very small addition to the airspace categories. All a VTOVL will need is a "bucket" of airspace about 5 to 10 miles in diameter and 60,000 feet high.

A VTOVL spaceship's noise footprint for takeoff and powered landing is basically circular. Thus, the radius of the airspace bucket can be a function of how much noise such a spaceship generates. Such a departure/arrival bucket means that a spaceport can be close to a populated area. Its radius is determined only by noise, not by the need to protect people and facilities



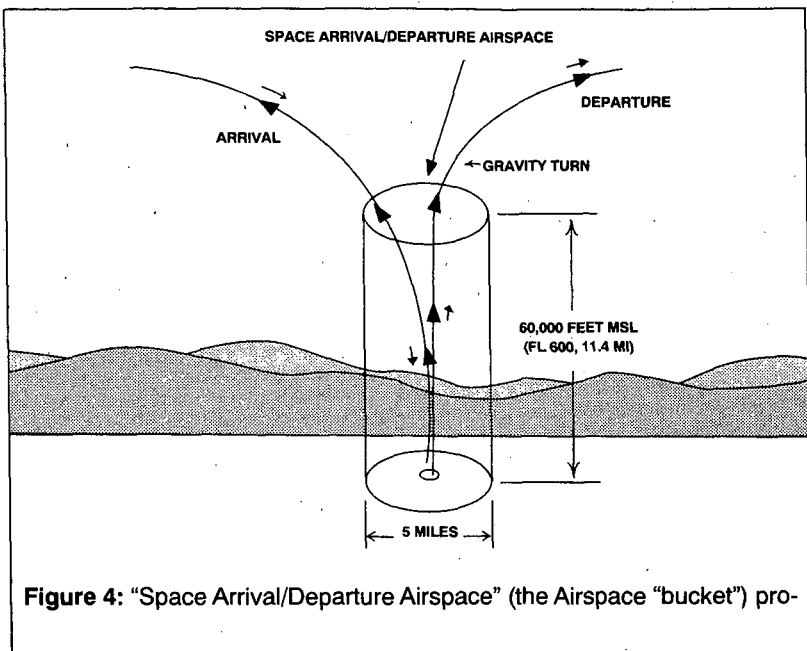


Figure 4: "Space Arrival/Departure Airspace" (the Airspace "bucket") pro-

in the case of a spaceship explosion as it is at the Cape. The reason everything and everyone is kept about three miles from the LC39 pad during a shuttle launch is the 1960s requirement that everything and everyone be at a safe distance if a Saturn V underwent a high-order explosion on the pad or shortly after liftoff.

A VTOVL like the proposed McDonnell Douglas Delta Clipper or the Kistler Aerospace K-1 could take off and climb vertically up through the airspace bucket to 60,000 feet, then execute a gravity turn and head toward orbit. On the approach, the spaceship can be slowed to subsonic velocities above 60,000 feet and aimed at the top of the bucket where it commences its vertical descent and landing.

Why 60,000 feet?

Because the FAA has jurisdiction over airspace up to and including 60,000 feet above mean sea level, period.

Above 60,000 feet, there is no federal jurisdiction over airspace. That is where "airspace" ends.

No international agreement exists defining where "outerspace" begins. The Federation Aeronautique Internationale in Paris says space begins at an altitude of 100 kilometers (62 statute miles) above sea level. The US Air Force awards astronaut wings to pilots who fly above 50 miles.

Who controls the volume of air/space between 60,000 feet MSL and 327,360 feet MSL (62 miles)? Who can approve or disapprove of the passage of any vehicle through

that region? Answer: As of this writing, no one knows. However, since the flight of Sputnik 1 in 1957, the principle of the right of innocent passage of spacecraft over a nation's airspace has been tacitly accepted. With the reusable commercial spaceships, this issue alone will likely keep lawyers and diplomats busy for years.

As a reality check, the concept of the VTOVL spaceship airspace bucket was run past the FAA airspace people in Phoenix, Arizona. Their reply was encouraging: "We could live with that. However, the regulations and procedures must come from FAA Headquarters."

A number of legal issues have been mentioned already. There are others that must be considered. Opinions must be rendered concerning the applicability and legality of some. Other legal issues perhaps will require modification of existing treaties, conventions, laws, and regulations. Some will require that new ones be developed. This is a consequence of considering spaceships as very high performance aircraft.

If reusable spaceships are considered as high-performance aircraft, do any precedents exist in air law that might apply to them?

The 1957 United Nations General Assembly Resolution mentioned previously states that air law applies to spacecraft operating in airspace. Other international treaties and conventions may apply as well. These need to be scrutinized from the viewpoint of applicability to commercial space activities. Among them are the following:

The first international convention

or treaty having to do with aviation is the *1919 Paris Convention Relating to Regulations of Aerial Navigation*. The United States did not ratify it.

The *1929 Warsaw Convention on Unification of Certain Rules Relating to International Carriage by Air* is referenced on the back or as part of every airline ticket. Among other things, it has to do with how much the airline must pay a passenger for damaged or lost luggage. The Warsaw Convention has other aspects that may apply to commercial space transportation. It needs to be looked at in this regard by competent air law experts.

The same can be said for the *1944 Chicago Convention on International Civil Aviation*. That basically had to do with markings of aircraft, registration criteria, etc.

The *1948 Geneva Convention on International Recognition of Rights in Aircraft* has to do with civil rights of passengers while on flights in international airspace, among other things. It also covers such matters as the national laws that apply if a citizen of Nation X commits a crime against a citizen of Nation Y in an aircraft registered in Nation Z when the aircraft is over the middle of the Atlantic Ocean. In common with much aviation law, this treaty has its roots in admiralty and maritime law. Therefore, it is quite likely that the law of air/space will have its roots in aviation law as well as the law of the sea. Lawyers as well as engineers find it easier to work with existing art and depart from there. As any author knows, it's very difficult to work from a clean sheet of paper.

The 1952 Rome Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface is interesting because of its similarities and differences with respect to the 1967 *United Nations Treaty on Principles Governing the Activities of States in the Exploration of the Moon and Other Celestial Bodies* (the "UN Space Treaty") and the subsequent *UN Convention on International Liability for Damage Caused by Space Objects* (the "UN Liability Treaty"). The Rome Convention states that the owner of the aircraft causing the damage, not the nation of its registry, is liable while the UN Liability Treaty states that the nation of registry of the spacecraft is individually and severally liable for any damage. Herein lies a basic conflict that is certain to come before the World Court in The Hague unless the differences are rectified. Recall that a 1957 UN General Assembly Resolution, a non-binding declaration, says that a spacecraft is subject to air law while operating in airspace. Imagine a scenario in which a spaceship suffers a failure while passing through 62,000 feet MSL on its descent to landing. As a result of a sequential catastrophic disassembly of the spaceship as it falls through airspace, damage is caused to people and property on the ground. Which treaty applies? Some lawyers will undoubtedly be very busy in this scenario.

Law strongly depends upon precedent. There are many conflicting precedents in federal law, too. For example, in 1925, the United States government stopped flying the airmail. The Postmaster General put a large

number of airmail routes out for bids. Hundreds were received from little companies no one had heard of before. Outfits like Robertson Aviation and Varney Speed Lines got airmail carriage contracts. Varney Speed Lines later became Continental Airlines. This action on the part of the Postmaster General was the basis for the formation of the airline industry in the United States.

However, people took this a little bit farther, pushing the edge of the envelope as they always have. By 1932, Boeing Airplane Company had formed a conglomerate that included itself as an airframe manufacturer and United Air Transport, an airline operating company. Boeing built a sleek twin-engined airplane called the Boeing 247. This was much faster and more economical to operate than the Curtis Condors or the Ford Trimotors everyone else was flying. United Air Transport got the first 60 delivery slots for the Boeing 247. American Air Lines, a United Air Transport competitor, wanted some Boeing 247s so they could compete. The Boeing executives smiled and told American they would have to wait their turn. American could have #61 off the line four years hence. Transcontinental and Western Air (TWA) got the same response, so Jack Frye of TWA told the airframe industry his airline would be interested in buying a tri-motored Boeing 247 clone built to TWA specs. The result was the better Douglas DC-2.

It also brought congressional action in the form of the Airmail Act of 1934, also called the Black-McKellar Bill. This contained an anti-trust provision

that prohibited airframe manufacturers such as Boeing from owning an operating company such as United Air Transport.

The exact status of the anti-trust provision of the Airmail Act of 1934 is unclear at this time. However, since some aerospace companies seem to believe they're going to operate these new reusable airplane-like spaceships themselves or through wholly-owned subsidiaries, will they run afoul of anti-trust legislation or even the provisions of the Airmail Act of 1934? Some people at Boeing say it doesn't apply. However, Boeing was one of the companies that was bitten by this anti-trust provision more than 60 years ago! Perhaps the resolution of this question won't come until FedEx wants to buy 12 Boeing-McDonnell Space Clippers and discovers they'll have to wait four years for a delivery position because a Boeing or McDonnell Douglas operating subsidiary is scheduled to get the first dozen ships.

This article has discussed some basic legal and regulatory issues that few people seem to have addressed to date. Undoubtedly, more exist. They are not trivial. International as well as national issues are involved. As the commercial space bandwagon begins to roll, more people will clamber aboard because the purpose of commercial space activities is to make money. However, com-

mercial space activities may never get off the ground or may be delayed if these non-technical matters are ignored.

We have a recent example of this. Back in 1982, Space Services, Inc., a Texas-based space entrepreneurial company founded by David Hannah, Jr., wanted to fly a private rocket, the Conestoga, from private land on Matagorda Island on the Gulf coast of Texas. If it had not been for the intense efforts of Arthur M. Dula, a Houston attorney, the flight of the Conestoga would have been stopped cold by diplomats, politicians, and bureaucrats. As it was, it cost more than the rocket itself was worth to get all the permits and licenses demanded by various government agencies. Dula got the final approval for the flight less than 24 hours before the Conestoga took off.

So don't say that it can't happen again.

The question remains: *Will they let us fly the spaceships?*

Only if we face the issues now and begin to solve the non-technical problems at once.

The Roman philosopher Anicius Manlius Severinus Boethius (480?-524?) once wrote in his *De Consolatione Philosophiae* ("The Consolidation of Philosophy"), "*Superata tellus sidera donat*" ("Overcome the Earth and the stars shall be yours"). Now we know what he really meant. ■

This article was prepared from a transcript of a talk given before the "Space Access '95" convention in Phoenix, Arizona on April 22, 1995. The author is a member of the Arizona Space Commission.

Reality has a perverse habit
of shattering preconceived
notions about how things
will happen!

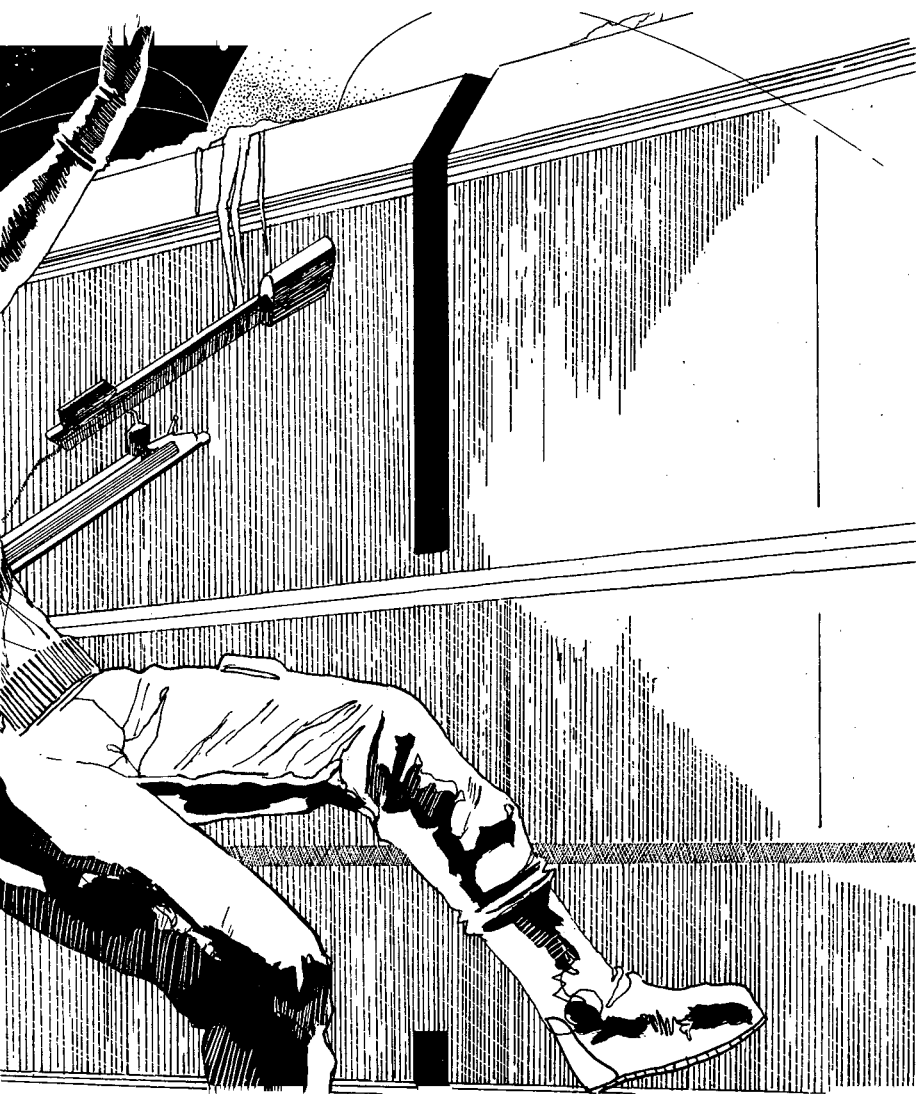
Illustration by Vincent Di Fate



James C. Glass

DIRTY SNOWBALLS

LICENSED TO UNIZORK
ELECTRONIC REPRODUCTION PROHIBITED



LICENSED TO UNZ.ORG
ELECTRONIC REPRODUCTION PROHIBITED

Leon Gratz was nearly finished with his second EVA day-shift when it began to snow.

He was working on the port instrument pod forward, and had just inserted a replacement power pack when the first flakes whirled in front of his faceplate and stuck there.

He wiped the plate with a thickly-gloved hand, but it didn't help much.

Snow swirled about him in a sudden flurry, blowing in from his right, the direction of the infant star spewing out its first plasma wind into the dense molecular cloud the *Orion* had been probing.

Leon looked towards the star, his vision blurred, and saw something bright and huge hurtling towards him. "Zeke, I got a problem out here," he gurgled into his throat mike.

"We see it, Leon. Better get back in here quick!" Behind Zeke's voice was the shrill shout of the emergency claxon.

"On my way," Leon replied.

He pulled on his tether to the mid-ship access hatch, and began hand-over-handing his way back, pausing to claw snow from his faceplate, amazed at the sight of it *flowing* on his glove like liquid, then freezing into ice and sticking his fingers together. The buildup on the hull was moving too, flowing like some plastic thing around pods and extensors towards the dark side of the ship. The flurry intensified, and he was blind again, pulling hard on the tether and panting for breath. Hyperventilating? He willed calm, but the suffocating feeling wouldn't go away, and his arms felt numb. "I'm not getting air!" he yelled.

No answer. Leon pulled hard, black specks dancing on the white nothingness in front of him, then he was slammed forcefully into the hull, ears ringing. His hands lost the tether and he flailed as something jerked at him, battering him back and forth before consciousness faded.

Fresh air, voices, the hum of the ship. "OK, Leon, OK, you're back inside now. Jesus! You're a mess!"

He was lying on his back in the airlock, and Zeke Peltros was kneeling beside him, pulling at his gloves. "Sorry about the rough entrance, but that stuff was *pouring* in here."

The airlock floor and walls were covered with dirty slush melting before his eyes, globules detached by the ship's vibrations floating lazily about them. Zeke waved some away from Leon's face, pulled him upright with the aid of a fuzzy-faced tech II Leon didn't know. "Let's get out of here before we breathe any of this stuff. God knows what it is."

The two men dragged him through the interior lock to suit-up bay, and by the time they got him unfrocked, the suit was a dripping mess of water and greenish slime, smelling like methane. Zeke wrapped the suit in plas-sheet, and gave it to the tech. "Take it to Boris. He'll want to analyze this stuff."

The tech left in a hurry. Leon felt cold, and the sewer smell in the room made his stomach queasy. "What the hell happened out there? We ran into something."

"More like someone threw a dirty snowball at us out of nowhere. We caught the edge of the thing, and the

rest of it kept right on going." Zeke fiddled with Leon's environmental pack. "Here's the problem, I think. Your return line is frozen. That snow must be *super-cold*."

Leon shivered. "I'm cold to the bone, Zeke. I need to dry out."

"Checkup first," Zeke said. He hustled Leon to sickbay, then left to report to Captain Waisley. Meanwhile, the pudgy little doctor thumped, poked and prodded Leon—checking every orifice—finally did a scan, then ordered him to take a shower. "You smell like shit," he said. "Don't you guys take baths?"

"It's that snow-stuff," complained Leon. "It sticks to everything, like grease!"

The smell seemed to go away after a hot shower. Leon put on a fresh jumpsuit, and found Zeke and Captain Waisley waiting for him in sickbay. Waisley cared about his work crews. He was the best captain Leon had ever served under. The fisherman's cap he wore made him seem more a part of them, but the white beard and cold, intense stare of those blue eyes reminded them of his many years of probe-ship command. He took Leon by the arm and sat down next to him on a cot. "What happened out there? What did you see?"

Leon told him, including the part about the flowing snow and ice. Waisley listened carefully, looked up at Zeke's thin, scarecrow face. "The stuff hit starboard and is all portside, now, clogging up half our reaction ports. Figure that one out."

"Ice that flows like water?" Zeke asked.

"That's what I saw," said Leon. "Did it on my glove, too, like it was trying to get in between my fingers."

"Whatever it is, we have to get it off, and quick," said Waisley. "Half our maneuvering capability is gone. Those ports are clogged, and the stuff is a meter thick in places. We'll have to torch it."

"It's not just ice, Captain," said Zeke. "There's a lot of organics in it. You can smell 'em when the stuff melts. Cogs is doing an analysis now. We'd better find out what we're burning out there."

Waisley nodded. "OK, but make it fast. I don't like drifting so close by a T-Tauri star when it's getting as near to ignition as our neighbor out there. That last burst of plasma wind saturated all our detectors; it probably blew that snowball right into us. God knows what kind of primordial goo is floating around in a molecular cloud as thick as the one we're in. Hell, we have planets and new stars forming in every direction here, and now I've had to power-down."

The captain turned to Leon, clapped him on the shoulder. "Glad you're OK, Leon. You get some food and sleep. We'll need you for EVA again, and soon, but if that's too quick for you I'll understand. You had a bad experience out there."

"I'll be ready, Captain," said Leon. "You just say when."

"Good." Waisley gave Leon's shoulder a squeeze. "Zeke, you call a crew briefing for ten-hundred tomorrow, and get command on the horn for me. They'll wonder why we've stopped moving."

"Yessir," said Zeke, and he hurried away. Leon followed Waisley out of sickbay, went to mess for coffee and what the synth-dispenser described as meat loaf and cheese potatoes, then retired to his cubicle and sacked in, falling asleep immediately.

He dreamed about snow, and was awakened twice by the faint odor of methane in the air.

The briefing was thirty minutes late because Cogs refused to leave his laboratory for it. Waisley settled for a written brief, and let the man do his work. Next to the captain, Boris Cogs was the power on the ship; half the budget of the expedition to this big molecular cloud complex was invested in his lab. Even the EVA crew knew why. Their sole mission, funded by eight planets in the Procyon Triad, was to map and economically evaluate every stock of hydrogen and organics within a hundred light-years—a job now twelve years old and just getting started. The cloud they drifted in now was the richest they'd encountered, and the T-Tauri protostar had been an exciting bonus for the astronomers back home. It had been analytical heaven for Cogs, and now he had a new toy to play with: ice that flowed like syrup.

The crew of six was bloated with coffee when Waisley finally returned from lower deck, one sheet of print-out in his hand. "OK, listen up. The stuff was water ice, loaded with organics. So far Cogs has identified nine amino acids, along with whole fragments of proteins. Among other things. 'An organic soup looking for a

warm ocean to fall into.' That's Cogs talking."

Somebody chuckled. Despite Cog's dreaminess, he was liked by Leon and the rest of the crew. Never condescending, he even drank with them occasionally, laughing at their dirty jokes, and his almost childish enthusiasm for his work could infect you like a virus.

"The stuff freezes at two-fifty Kelvin. Acts more like water bound to protein than normal water. Real viscous stuff, binds hard to everything. That's it, so far."

"That mean we can't scrape it off?" asked a crew member.

"Maybe. Boris wants you to try chipping it first. He wants a solid sample, a few kilos at least. All he had to work with was the liquid from Leon's suit. I told him what I'll tell you: try the chipping and scraping, but not for long, then take the flamers to it. I want to be totally operational in forty-eight hours."

"When do we go out, Captain?" asked Leon.

"Two hours. That T-Tauri has flared again, and we should see another plasma burst within the hour. The thing is pretty irregular right now, so when you're out there, stay on the dark side of the hull. Take hammers, chisels, and flamers, and get a nice block of dirty ice for Cogs. He seems to think it's something entirely new. Other questions?"

There weren't any. Then Zeke spoke up: "Captain, another thing I'd like Boris to look at. We're getting a lot of broad-band noise now in communications. Pretty flat spectrum, ex-

cept for some peaks around a micron, and a sharp one at ninety meters."

"Cloud emissions?" said Waisley.

"I don't think so, sir. Wasn't there before the snowball hit us. It's not a problem, but I thought you should know."

"OK. I'll run it by Cogs. Better start suiting up."

Leon was paired with Arnie Solvido on the list Zeke circulated. Arnie was a good man, strong but easygoing, a slow breather with not much to say. Leon had pulled over a week's work on the man's tether with only a handful of words exchanged. Just the way Leon liked it—outside. Arnie showed up with a twenty pound sledge to go with the smaller tools and flamers they were going to try on the mass of starboard ice mounded on the hull, clumped in blocks at beam intersections of the instrument trellis. They saw all this with the forward video-cam. Right at the sun-line, it was the only instrument not covered with ice.

Six of them suited up an hour after another blast of plasma wind had raked the port side, carrying with it icy particulates that scoured metal like sandpaper, making an audible screech they could hear inside. Space in this dense molecular cloud was not so empty. And Leon still remembered the freezing snow with its flowing ice.

They tethered up at the port hatch and went out by twos, Leon and Arnie last, winching out three tool packs, each with flamer, then moving quickly to the dark side of the hull.

Up close, the job looked bad: a solid, amorphous-looking mass of dirty ice up to a meter thick, covering vents and reaction ports. During the first hour they whacked at hull ice, Arnie swinging the big sledge, Leon working with a five-pounder and chisel. Solid ice, no layering or cracks to work with, bonded ferociously to the hull. In minutes they were surrounded by a cloud of ice chips and fist-sized chunks, pushing them away from the hull into *Orion's* shadow. Leon finally called in.

"Zeke, this is going nowhere fast. It'll take weeks to break this stuff up, and chisels won't get it off the hull. I say let's flame it."

It was Waisley who answered. "OK, but get some samples for Cogs first. Big chunks, if you can."

What they got was a couple of soccer-ball-sized blocks Arnie had whacked off. They trundled them back to the lock, then broke out the hydrogen flamers as Zeke came on the line.

"See anything out there? The radio noise has gone way up since you guys started working."

Leon looked around from the dark-side, the cloud of icy debris dully illuminated by girder-scattered light from the T-Tauri, beyond it only a few stars showing through channels in the thick molecular cloud around them, streaks of red and green far off where a newly born star was glowing. "Just the cloud," he said. "Flamers on, Zeke. This should go a lot faster."

And it did—at first. At ten thousand Kelvin the flames flashed the dirty ice to vapor on contact. But

then the most amazing thing happened.

The ice began to move.

A flamer would make initial contact, flashing vapor at a point, and beyond that point the ice seemed to slump, color suddenly greenish, changing shape and *flowing* away from the flame. "What *is* this shit?" growled Arnie. "It's running away from the *flame!*"

"This ain't no ice," said Leon. He'd held his flamer at a shallow angle against the hull before a man-sized mound of ice covering a reaction port, and watched the entire mass retreat to form a thick shelf beyond the port. It had moved a full meter in seconds. The port itself was still clogged. He blasted it, saw ice flow out in all directions away from the flame as he went in deeper and deeper, and suddenly the port was clear all the way down to the reaction nozzle throat. "It's working!" he shouted. "We can clear the ports out with flamers, but we're not melting the stuff. It's flowing away from the heat!"

Now it was suddenly a game. Three flamers, pushing masses of ice around without effort, but it was eerie, watching that stuff move like it was alive, running away to escape the heat. When Zeke came on line, his voice was nearly obscured by a hiss.

"Get the other reaction port cleared out first. Once we roll the ship, the sunlight and plasma wind will take care of the rest."

"We can barely hear you," said Leon.

"I know. The radio noise is all over the band now, and getting stronger.

Clear the port, and get back inside."

Zeke sounded a bit anxious, and that bothered Leon. The ice had retreated to the sun-line, forming a two meter ridge forward to aft, though untouched blocks still covered girders and instrument pods in the superstructure. Three flamers went to work on the remaining reaction port, and ice flowed like milk, but then Leon caught something in his peripheral vision and looked up.

Something huge and white filled half his view, rushing towards him at terrible speed on a collision course. Its center glowed like a giant, green eye, and tendrils extended before it, reaching out towards them. Leon lurched backwards, and dropped his flamer.

"Get out of there!" screamed Zeke. Then the ice storm hit, the first tendrils reaching for the three flamers and snuffing them dead. Icy slivers, sleet and snow crashed into them, knocking them down, and Leon felt a terrible cold come with it.

"Arnie!" he yelled, and felt a gloved hand on his arm. "Move fast, before we freeze up! Everybody move!" He felt Arnie scrabbling at his back, the jerk of the tether behind him like a fish on a line, four other men stumbling blindly to their feet in swirling whiteness. But nobody panicked, not this crew, and in seconds they were back to the lock, already open for them. They tumbled inside, tools and flamers left behind on the hull, and the T-Tauri was glaring at them as the hatch slid shut.

"What the fuck was that?" asked one of the crew.

Leon brushed greenish slush from his suit. "The dirty snowball that hit us," he said. "It's come back."

"It's sitting about two clicks off, right in our shadow," said Waisley. "It backed off after you came inside, and the one reaction port is still clear, but all your gear is frozen to the hull."

"We've got plenty more flamers," said Leon. Now he was angry, and he wasn't sure why.

"You want to go outside with that thing hovering around? The one fact obvious to me is that it was going right for the flamers. It didn't give a damn about you guys. Once the flamers were gone, it backed off."

"You make it sound intelligent, Captain," said Zeke. "Maybe it is. Cogs thinks so."

They were still wet, sitting in the briefing room with tubes of scalding coffee in their hands. The air in the room still smelled like methane. "If he's right, then we owe the fucker something," said Leon. "It tried to kill us out there. Let's roll the ship, let the plasma wind take care of the rest of that ice, and get the hell out of here!"

"I think he's right, Captain," said Zeke. "That T-Tauri is flaring several times a day, now. It might be a thousand years until it ignites, or it might be a day. I'd just as soon not stick around to find out. Let's roll the ship, clear off the ice, and get out of here."

"I don't think we should be so quick about that," said someone behind them. Cogs. He stood in the doorway, arms folded, a mop of hair down over his eyes, thick lenses giving him a bug-eyed look. He rubbed

his chin reflectively. "At the same time, I find it curious that our visitor left the one reaction port open, when it could have filled it up again. We're not just dealing with a dirty snowball, gentlemen."

"Yeah. *You* think it's alive," said Leon sarcastically.

Cogs got a tube of coffee from the dispenser and sat down with them. "I didn't exactly say that. What I said was that it shows directed and purposeful behavior. Call it intelligence. Or simple, programmed logic if you like, but the thing is directed, and it's communicating. That piece you brought in for me is sitting in the lab right now, chirping away in a broad band with a peak around one micron. There's your radio noise, Zeke. It's coming from the ice on this ship. And my bet is the ninety meter peak is coming from the snowball itself. A part of it is stuck to *Orion*, and the snowball wants it back. When you started flaming, it returned to remove what it perceived as a threat. It's probably been lurking out there in the cloud ever since we collided with it."

Leon thought of the glowing eye in the center of the snowball rushing towards him, the tendrils reaching out like claws towards the flamers. And cold. "So why did it hit us in the first place? I nearly died out there, Cogs."

Cogs nodded. "I know, but that could have been an accident. It was outbound and just ran into us. A direct collision would have splattered *Orion*, and my guess is it made a course correction the instant it saw us."

Waisley looked thoughtful, raising

an eyebrow. "It was moving out—away from that T-Tauri star?"

Cogs smiled briefly, then said, "Looking for a cooler place, Captain. It's probably had tens of millions of years to evolve while that star was moving down the Kayashi track to ignition, but now something's about to happen, and whatever we're dealing with is trying to get the hell out of here. For all I know, the star has already ignited, and the energy just hasn't reached the photosphere yet. We can't detect neutrinos, but maybe the snowball can."

"Jesus," said Zeke. "It could get hot here in a hurry. We're less than an A.U. out from that thing."

"But not as vulnerable as exposed ice," said Cogs. "You've seen how sensitive it is to temperature. There's an organic matrix in that stuff, a matrix it'll take me months to figure out, even with the Cyber II back at base. Too cold and it's immobile, but communicative. Too hot and the matrix breaks up, ceases to function. In other words, it dies."

"We were killing it with the flammers," said Leon, his anger suddenly tempered. "But if that star blows, and it's us or them who survives it, then my vote is for us. That ice has to come off the hull."

There was mumbled agreement among the men, including Cogs. "I have an idea for doing that," he said, "but we'll have to move slowly with the snowball watching us. And its participation will be vital. It has to figure out what we're doing, and have time to react to it."

"OK," said Waisley, "let's hear it."

Cogs proceeded to outline a simple yet crazy and delicate plan none of them believed could happen. Midway through the conversation, Zeke left to see if the snowball had changed position. When he returned, Cogs had finished, and everyone was ready for a meal and some sack time.

"We have a new development that doesn't do your plan any good, Boris," said Zeke.

"What the hell has happened now?"

Zeke shook his head. "Your snowball has disappeared."

"Shit," said Cogs softly.

"So let's break out the flammers and get at it," Arnie growled, the only thing he'd said during the entire meeting.

"No!" shouted Cogs. "Captain, we've got to wait, even if it's just a few hours. There must be a reason that thing has gone away."

The men groaned.

Waisley thought for only seconds. "You're all tired and hungry. Take care of that first; then we'll decide. Get to it."

Everyone headed to mess, Cogs still pleading his case with Waisley as they left the room.

Thirty minutes later, drinking coffee over the remains of still another unidentified meal, they heard the screech of a horrible plasma wind raking the sunward hull of the ship.

Leon was finishing breakfast with Arnie and the others when an intercom call from Zeke ordered them immediately to suit-up bay. "Looks like you'll get your wish," said Leon to

Arnie, but the man scowled and just said, "About time."

So much for morning conversation with Arnie Solvido.

When they got to the bay, Zeke was watching the big monitor screen. He pointed to it, and what they saw sank their expectations into oblivion. "Snowball's back," said Zeke, "and it brought a couple of friends along with it."

Three glistening orbs showed on the screen, two much smaller than the third. "The big one is a klick off," said Zeke. "The two little guys are only three hundred meters out, sitting right in our shadow. They moved in a couple of hours ago from that dusty cloud patch at eleven o'clock, streaming trails of vapor that Cogs says is normal water. And the radio noise is terrific, now. Waisley is going ahead with Cog's plan, crazy as it sounds, but he wants you suited up to clear out that last reaction port if things don't go right."

They got suited and racked up six flamers this time, one per man. One port, six flamers. Could they work fast enough, before those things moved in to stop them? Leon suddenly felt like he was readying for battle, and he was sweating immediately after his suit was on.

The ship shuddered for one instant, and the orbs moved downwards on the screen, Zeke bringing them back to center with his camera controls. Another shudder, and motion ceased on the screen.

"A small rotation, and the top of that ice ridge should be warming now. It was right at the sun-line,"

Zeke said.

The small orbs on the screen grew larger, the big one remaining as it was. "They're coming in, just like Cogs said. The guy is amazing," said Zeke, then, "Switching to forward cam'."

What they saw astonished them, the sight of a two-meter high ridge of ice rippling, undulating, rising to a crescent-shape peak to wave like cloth in a gentle breeze. Zeke switched back, and the entire screen was filled with a cloud of glistening crystals.

"They're coming for it, Captain!" shouted Zeke. "They're right on us!"

"We're watching," came the reply.

Zeke switched back as *Orion* shuddered again, then again. Another short rotation. The ridge ice was flowing from base to crest, now, stretching several meters above the hull, waving like a field of grain, and then the blackness beyond was covered with sparkling white, visible tendrils reaching towards the dancing crest, fanlike, moving along it to form a bridge along which ice flowed as if sucked on by some giant mouth. As they watched, astonished, the entire ridge, thousands of kilos, flowed upwards and across the bridge, leaving behind the dull yet unmistakable clean surface of the hull.

"They sucked it up!" said Leon. "They actually did the job *for* us. How could Cogs figure that would happen?"

"They're taking back the part of them they almost left behind," said Zeke softly, and there was a kind of reverence in his voice.

Leon barely noticed the sweat pooling in his suit. He watched in awe as

Orion continued its slow, methodical rotation, the big snowball maintaining its distance, the small ones dutifully sucking up ice as it became warm enough to flow. Last to go were the chunks in the superstructure, the mass deep in the reaction port, fine tendrils reaching out gently to form a narrow bridge for the flow. And then it was clean; every square meter of hull and superstructure was barren of ice.

They waited for the two smaller snowballs to retreat.

The dirty things stayed where they were, hovering only meters from the ship.

"Now what?" said Leon. "Why don't they go away?"

"Zeke?" said Waisley over the intercom.

"We're watching them, sir."

"Well, they're not moving, and we've got to inspect that reaction port before we get underway. Someone's going to have to go out and check it. One small ice plug would be enough to blow the nozzle throat out when we fire up. Get someone on it."

"Got it, sir," said Zeke, and Waisley clicked off. Zeke looked at them, shrugged his shoulders. "Any volunteers?"

Someone laughed, but otherwise there was silence in the bay. Leon looked at Arnie, but the man only rolled his eyes at him.

"Come on, men, one or two to make a quick check on the port, then back inside. The hull is clear."

"Those things out there are nearly close enough to touch," said Leon. "Maybe they're just waitin' for one of

us to come out, to get back at us for using the flamers. You ever think of that?"

"I hear you," said Zeke softly, "but I don't believe it, Leon. Not after what we've just seen. There's some kind of brain behind all that ice and snow. They know exactly what they're doing, and I don't think that includes waiting around for a human sacrifice."

Zeke stepped up and put a hand on Leon's shoulder. "How about it? You've been out there twice with dirty snowballs all over you, and they haven't killed you yet." He smiled.

Zeke was right; first time probably an accident, second time when they were using the flamers. Leon swallowed hard, and said, "I ain't taking anything out with me, no tools, no flamer. And I want Arnie to anchor my tether in case they try anything."

"Thanks a lot, Leon," snarled Arnie.

"Just stay by the hatch, and pull me in if they make a move. *I'm* the one taking the chances!"

Everyone was looking at Arnie, and Leon knew he had him, even when the man glared back. "You'll owe me for this, buddy."

Leon nodded, and slapped Arnie's shoulder. And ten minutes later, the hatch slid open, and they were looking at the roiling mess that was a baby star trying to get born, deep red polar jets spewing forth with force against expanding, boiling clouds of gas and dust. Leon hooked up, Arnie locking in at the anchor point a meter from the hatch. "Two tugs," he said, "and I'm pulling you in, standing or not."

Leon rapped Arnie's helmet with a

gloved fist, and grinned. In four strides he was at the sun-line, and the two snowballs were rising like star clusters above the hull, masses of crystals sparkling, faint, green glows at their centers—pulsating. He'd misjudged their distance, or maybe they'd backed off, but they filled his vision, hovering several meters off, each nearly the diameter of *Orion*. He took a deep breath, exhaled slowly and marched straight to the reaction port, bent over, looked inside. Clear. "Port's cleared out!" he shouted.

"We hear you," said Zeke. "Make a hull check while you're at it, and grab anything loose."

Leon walked the hull twice, fore and aft, neck getting tired from jerking his head around to keep one eye on the snowballs. "Tools and flamers are gone. I guess they were blown or sucked away. All clear out here. Now what?"

"You're done. Come on in, Leon," said Zeke.

He was back at the sun-line where he'd started, and turned one last time for a close-up look. His heart nearly stopped.

The snowball on his left had suddenly moved closer, was nearly on him. His hand tightened on the tether, ready to jerk hard.

The snowball stopped, drifting so close he could take two steps and stretch out to touch it. The greenish pulsation was suddenly mesmerizing. He stared at it for a second before exasperation overcame his reverie. He held his arms up from his sides and waved them like an injured bird. "Why don't you go away? What the

hell do you want?"

Leon Gratz would never forget what happened then. He talked about it for weeks after, until the crew was sick of it.

As Leon lowered his arms, a tendril of icy stuff the size of a man's arm snaked out from the snowball, its shining tip fluttering like smoke near his face. The tip suddenly bulged, a fist-sized chunk breaking off to float within a meter of his faceplate. And then the tendril reached out again, wrapped once, twice around the icy piece, drew it slowly, gently back into the mass from which it had come.

"Oh, shit," said Leon. His face was flushed, yet his body was soaking wet and freezing.

"You back inside, yet?" asked Zeke.

"He's just standin' there," said Arnie.

"I'm OK, I'm OK! Zeke, does Cogs still have those chunks of dirty ice we brought in?"

"Well—yeah. They were still chirpin' away in his lab a couple of hours ago."

"Zeke, I think these things want the chunks back. I think they're signaling to each other, and that's why they're hanging around. I'm willing to bet money they won't leave until they get everything back."

"I'll tell the captain; you hang on. Leon, you OK out there?"

"Yeah—yeah, I'm fine. Just get the ice."

"We don't have air out here forever," said Arnie.

"Thanks for reminding me, Arnie."

"Well, we don't. We're out here, and they're not. Can you see Cogs giving up his precious ice sample?"

"That's what captains are for, Arnie. Take it easy."

They waited—and waited, Leon nose to nose with the snowball, Arnie cooking sunside and giving an occasional, irritating tug on the tether to show his displeasure. *Finally*, Zeke came back on line.

"OK, we got it. Cogs understands. He doesn't like it, but he understands. He's up to his ass in data on this stuff anyway. We're bringing it out in a bucket, and right away."

"I don't think I'd better move," said Leon, staring into that greenish glow. "This guy might take it the wrong way." Even saying so, he somehow didn't believe it. The glowing ball of snow and ice with the pulsing green heart just floated there, as if it knew what was happening. An organic matrix in water ice. A brain?

"You stay there, Leon." said Arnie. "I'll bring it out if you just stand still."

Leon knew fright when he heard it, but Arnie would do what he said he'd do. He was that kind of man. In a moment he felt a tug on the tether, and snapped a glance over his shoulder. Arnie had hooked himself up to the tether, was shuffling up to the sunline, head down, a bucket dangling from one hand. When he neared Leon, he looked up, and his eyes were huge behind the faceplate. He put a stranglehold on the tether with one hand, gingerly held out the bucket at arm's length with the other, and stopped where he was. "Here, take the damn thing," he muttered.

Leon leaned back to take the bucket by its rim, felt the mass nearly filling it, looked inside and saw flicker-

ing, emerald flashes in black ice. He pulled down on the bucket, and the mass floated free at his waistline.

"It's got to heat up, Léon! Get it up in the sunlight." It was Cogs on the line, not Zeke.

Leon left the bucket to float beside him, took the sparkling chunks of ice in both hands, held them up to the snowball like some kind of offering, then raised them over his head and poked them with a finger. The chunks rose slowly, rotating slightly, and for a long, horrible moment the two men stood before the *Orion*-sized snowball—waiting for a reaction.

Nothing, at first, the ice chunks a meter off, then two, tumbling still. And then they began to change: first dirty ice, now a dark green, then lighter, changing shape, flowing into a single mass and spinning faster, twisting into a coiled cylinder. The cylinder writhed like a snake, stretching out towards the snowball as a tentacle of white stuff emerged there to grasp it like an elephant's trunk taking a peanut. It was gone in a flash, sucked up like all the other ice on the hull.

"Jesus," said Arnie, barely audible to Leon, the sound of his own heart-beat pounding his ears.

There was nothing else to say, and all they could do was stand there and watch as the snowball backed off to where its companion waited. The things turned together, moved off slowly, and suddenly the space around the two men was sparkling in crystals of flawless white, a light dusting of snowflakes pure as spring water. They stood gaping for minutes,

until the two snowballs joined the bigger one, melding into its sides, disappearing into it. The big one pulsed green, turning, its emerald glow steadying, and then it moved away, slowly at first, trailing a sparkling plume that widened as the thing suddenly accelerated. In seconds, it was only a bright spot flickering in and out within the dust lanes of the dense nebula beyond.

"Good job, guys. Time to come inside," said Zeke.

"Yeah," said Leon, still looking outwards. He followed Arnie back to the hatch, where Arnie leaned forward, their faceplates touching.

"Leon—those things out there—they're alive."

"I know," said Leon—and then they went inside.

Four months later, on their way back to the picket platform "Harrison," the entire EVA crew was just finishing breakfast in the mess room. A young tech was having a problem with one of the synth dispensers, and had started banging on it with his fist when Waisley walked in, and then the banging stopped.

"I have an announcement," said Waisley, grinning. "Molecular cloud complex 3G7 wishes to announce the birth of a new star!"

"Let me guess where it was born," said Leon.

"Cogs says the color-T is ten thousand Kelvin, but it'll settle down to

eight. A nice sol-type sun for whatever's out there."

"Good enough for snowballs?" asked Arnie.

"Could be. They seemed to know where they had to be. Anyway, we're gonna find out. As soon as we retrofit at Harrison, we have orders to go back out there to look for them."

Everyone groaned.

"Hey, this is important! First contact, and all that, and besides, there are some planets forming back there. It's our job to look in on them happening, men; don't forget what you signed on for."

"We gonna try talking to them?" asked Arnie.

"Maybe, if the scientists at base can figure out what we're dealing with. Cogs is their hero right now. He's in heaven."

"What the hell could we say to each other?" said Leon.

Waisley laughed. "I'll settle for a thank you," he said, then left the room.

The tech started banging on the synth dispenser again, and Leon jerked around to shout at him, "You got something against that machine, Keith? Jesus, the racket!"

"Pop's coming out warm again. Ice is gone. We never have any ice around here when we need it!"

And then he quickly ducked, to escape the barrage of wadded-up napkins simultaneously thrown at his head by every other man in the room. ■

G. David Nordley

THE KUBOTA EFFECT

*Sometimes it's real important to be able to
use the wrong tool for the job. . . .*

Illustration by Steve Canale



LICENSED TO UNZ.ORG
ELECTRONIC REPRODUCTION PROHIBITED

"Eureka!" Hiro "Jack" Kubota shouted and a thousand echoes answered from the empty halls of the deserted underground lab. He jumped, maybe half a meter off the ground—there was no one to watch him. With a trembling hand he selected "print" from the menu of his Granny Smith. Eight years in this surplus would-be superconducting supercollider tunnel, and, finally, he had done it.

The equipment sat there just like it had five minutes ago. But then it had just been an experiment. Now it was a compact antiproton factory, a prototype for something that could change the course of history.

It's going to belong to the Smithsonian someday, he thought dizzily; I'd better be careful with it. The power could go down, the data could be lost, he might be unable to replicate the experiment and there would be only his word—the nightmare of being the participant in another cold fusion fiasco paralyzed his hand. Print it! Now! he told himself, and shaking himself willfully out of that train of morbid thoughts, he tapped the key.

In moments, the pictures of the particle paths slipped into his printer tray. Hard copy. Permanent. Real. With trembling hands he picked up the sheets—it was beautiful, elegant, as something of such significance should be. The particle traces looked like a perfect symmetrical flower; positive pions curling left, negative pions right, protons curving left, a thin trace of fluorescence down the center where the neutral particles accidentally disturbed an electron or two, and

there, to the right, a firm, thick trace of antiprotons. Antimatter. Electricity in, antimatter out. He'd done it!

"Banzai!" Jack jumped high again, feeling for a moment he could sail through the dozen meters of rock and prairie above him like a neutrino. The old tunnels could not contain his joy. Still shaking, he sat down. He should make more measurements, file an e-mail note, tell Dr. Grimski. Take radiation readings—he hadn't really expected it to work so *well* and that stream of antiprotons represented several joules of hard radiation. He'd have to be careful not to endanger his and Gina's future children!

A tear of joy dropped on the print-out—careful, that's going to the Smithsonian, too. The pion traces were thin, delicate. They were the noise—careful tuning should eliminate them, and the neutrons and antineutrons as well. The protons couldn't be helped—but, he chuckled—so what! He had proof of principle that antiprotons could be made at efficiencies approaching 50 percent of their energy cost. That was revolutionary; antihydrogen made by solar power satellites could replace uranium and plutonium in power plants. Antihydrogen-powered rockets could fly to orbit like airliners, with airliner payloads. Doctors could attack cancer with a tenth of the normal radiation side effects. . . .

At least it ought to get him his doctorate!

Gina! He had to call Gina. He looked at his watch; she should be at the neutrino observatory, three kilometers down the curved tunnel.

"Artoo," he told his computer, "call—"

"Hold it!" a loud voice announced. It sounded as cold and solid as the concrete walls from which it echoed, and dripped with condensed authority.

Jack spun around in his ancient surplus swivel chair. "Who the. . . ." The sight of the gun in the man's hand shocked Jack into silence; he knew next to nothing about guns. This was large, smooth and squarish—nothing like a cowboy revolver, and no gadgets on it that he could see. The mean-looking hole in the end of it might have been a centimeter across. With the light from his desk lamp behind him, he could almost see into the barrel. "Who are *you*?"

"Don't even think of trying to find out, if you want to live." The speaker was wearing a black trench coat, as if out of a spy novel.

The face was very ordinary, though a little hard. Jack studied the face, trying to note details, but he knew he probably wouldn't recognize it in another context. He even had problems with Japanese faces, and he was raised there. Nonetheless, he noted that the hair was straight and black, with a touch of gray at the temples. The man was big, just under two meters and probably over a hundred kilos—twice Jack's mass. He could have been anywhere from forty to seventy.

The gunman carried himself as if he were used to moving quickly. Jack saw no sign of softness or flab—but no sign of malnourishment either. The hand that held the gun was very steady.

"Sit down and keep your hands on

your lap where I can see them."

As he backed into the ancient swivel chair, Jack's life passed in front of him—not the life he'd lived, but the one he hoped to have with Gina. A small college somewhere, a low pressure place where they could teach and do research. A child or two, a book written the way a textbook ought to be written. It could all be gone in the next millisecond. It wasn't fair.

"What . . . what do you want?"

"That." The gun pointed briefly to the apparatus, then returned to a boresight that must have been aimed between Jack's eyes. "I've been waiting. Thought you might make it last week. That's what I'm after."

"But, but it's big. It's all over the place. It would take days to take it out, especially if you ever wanted it to work again. And it only produces a few picograms—nothing of any practical use. Unless you have a brain tumor?"

Was that it? They'd been treating people experimentally at Fermilab for years, shooting antiprotons into brain tumors that couldn't be touched otherwise. It worked, but it was very expensive. Jack felt a moment of pity—a desperate man, his thinking perhaps already impaired, taking a wild risk when he had nothing else to lose.

"I'm not a doctor," Jack continued, calming now that he imagined he had a handle on the situation. "But it's not out of the question that we could try something like that. It would take a couple of weeks to get ready, but if you're really hurting I'm sure there are people who—"

A brief smile cracked the hard face. "I'm sure the people I work for will find ways of making money off this. Now, do you have some electrical tape?"

Jack nodded to a workbench across the tunnel from his desk. It was covered by a mass of miscellaneous equipment; flanges, meters, pliers, strangely shaped pieces of metal and plastic, and yes, no less than three rolls of colored electrical tape. Jack color-tagged his wiring, whenever he thought of it.

"Good. I want you to take a piece and cover up the infrared phone port before either of us says anything more. Don't even think of trying to do anything else." He motioned with his gun to the workbench.

Jack got up slowly, went to the bench and cut off a piece of tape. The phone box was on the utility pole next to the light switch a few meters down the tunnel. He walked to it slowly, thinking furiously. If he could leave just a little part of the dime-sized infrared pickup uncovered, he might get through by pointing his computer's transmitter window directly at the light box.

"Don't even think about it, or you'll lose everything," the man with the gun said, as if he were reading Jack's mind.

He was right. As long as Jack got out of this alive, they could put it all back together again. All he had to do was to keep cool and do exactly what this thug told him to do. He put the tape over the infrared window. No calls, no Internet. He was suddenly aware of the utter isolation of this sec-

tion of tunnel. The cleaning staff came by weekly and Gina occasionally, but other than that, he could—and had—spent weeks without a visitor. The gunman could have been watching him for days, and no one would have noticed.

Gina! With the phone out of order, she might come looking for him. And it came to him how important it was to have, in the world, at least one other person who cared about you on a daily basis.

"I—I should call my fiancée. She might come to find out what's wrong."

"Hah! Nice try, but I'll take that chance. Now, I have no intention of trying to cart the device itself away. You are going to explain how it works, give me copies of your equipment lists, layout plans, progress reports and anything else my clients might be able to use to duplicate your results."

Jack lowered his head, shut his eyes, and bit his lip. As he walked back to his desk, the gunman walked over to the phone box to check his work. He never came within two meters of Jack. Very careful, confident. As if he had been doing this successfully for a while. Jack's grandfather had been a policeman and often entertained the family with stories about how stupid most criminals were. But this man did not seem stupid.

"Come on. I know it makes antiprotons and I know it makes them more efficiently than anything else. What's the theory and how do you make it work?"

Commercial espionage? Who was

he working for?

"Now!" the voice commanded.

"Do . . . do you know about the Benton-Kubota effect?" Gina Benton had given him the idea. Her graduate student neutrino observations of Supernova SN 2012A, ten years ago, indicated that the insides of white dwarf stars behaved as if they had more particles than were accounted for by standard theory. He had done a brute-force numerical simulation as a senior that supported the idea.

"Nano-scale quasi-singularities? You pinch a field to a point where it can scatter things like it was a particle?"

Jack nodded his head slowly. The gunman had given him a crude description that bypassed volumes of controversy. He and Gina had finally published in 2017, when some of his early experimental data had come out of the noise level.

"I . . . I see it like this. The collision between a proton and a quasi-singularity momentarily dissects the proton and blows it up into a quark-gluon plasma bubble, we call it quagma—" Jack looked at the gunman, who nodded, indicating, Jack supposed, that he understood and that Jack should go on.

"But my quagma bubbles are constrained, predictable. Each—"

"Keep your hands *down*!"

Jack froze—he had started to gesture as if he were talking to a graduate student, forgetting the situation. He was notorious for his one track mind—his ability, or disability—to concentrate on one thing to the exclusion of everything else. Gina called it the Kubota effect. Slowly he low-

ered his hands and continued his lecture, concentrating this time on the gun barrel.

"Uh, the, each of the three quarks in the proton hits the maximum field gradient in turn and produces a quark-antiquark pair, which are separated inside the quagma by the imposed fields—the six positive quarks one way, the six negative the other. A field twist affecting the one-third-charge quarks more than the ones with two-thirds charge mixes the up and down quark beams of opposite sign.

"As the quagma bubble collapses, the six quarks glue together to form two protons and the three antiquarks form an antiproton. That's the tricky part—the triplets are energetically more stable, but if the bubble collapses too fast, they don't all have time to form and you get a lot of mesons, too. Each collision is as exactly the same as I can make it, except for a small time uncertainty, so they emerge in controlled directions. Instead of spraying a variety of particles all over the place, I get pure beams of protons and antiprotons. That's the idea."

The gunman nodded again. "I surmised something like that. Your incident protons hit an electromagnetic wall and split—viewed in the proton's frame of reference, it's just high energy gamma scattering. How can you control it?"

"I, uh, prefer to think of the pinch nexus as a very special captive virtual particle, but the electrodynamic description is equivalent. Anyway, I get a big long quagma bubble."

"OK, the net result is that you control what happens on a subnuclear

level deterministically so you make an antiproton for five times its annihilation energy instead of five hundred. How?"

"Well, almost deterministicary." Jack winced at his own accent as he wondered, who was this? What could a man in a trench coat and a gun know about twenty-first century sub-nuclear physics? "I need control over the quantum numbers for 1.3 picoseconds. The main innovation is a Bell-effect probability filter. It, uh, cheats the uncertainty principle by defining the spin phase of the incident proton in exchange for a tolerable momentum spread. The theoretical basis for the experiment is in my proposal."

"That's classified. Do you have a copy here?"

Jack shook his head. What was his responsibility here? Would anyone punish him for giving up the document at gunpoint? There were people who thought antimatter bombs were a possibility. That was nonsense, but you almost had to be a weapons physicist to understand *why* it was nonsense—and some professional technophobe-baiters took advantage of that to bask in a phony world-saving glory at the expense of researchers' livelihoods.

Was that what he was up to? Was he going to try to create a scandal that would convince the world that Jack's research was too dangerous to be allowed—and free up Jack's measly thirty grand a year for something else?

"Come, on, come on." The gunman waved the gun at Jack's filing cabinets. "You must have at least a draft here."

Jack trembled but didn't move.

The shot was the loudest thing he ever heard in his life. In the closed space, the shock wave rattling off the curved concrete sounded, incongruously, like a ping-pong game. When the echoes died down, Jack opened his eyes. The gunman waved the gun toward the filing cabinets again.

There was a slightly burnt odor about, with a sharpness to it. Gunpowder? Jack had never smelled it before.

"I . . . I'll look."

He found himself in front of the file cabinet without remembering how he'd gotten himself out of the chair and over to it. There was a bullet hole in the bottom drawer of the first cabinet. Jack did a quick mental inventory—his diploma probably had a hole in it now. There was a picture of Gina in there—maybe too far back. His late father's Ph.D thesis might have protected it. His college physics department chairman's "Retter of Recommendation," as the kindly but mischievous old man had called it in good natured mimicry of Jack's accent, was in front of the thesis. So that had a hole in it too, now.

This was a lesson to him for something. Of course. His display of pride at his success had been immediately punished, a load of karma to teach him the humility he had not shown before the powers of the Universe. He frowned deeply. Did he really believe that?

The proposal was in the top drawer. Jack's thumb print released the lock, he pulled the drawer open, found the section, and put his hand

on the document.

Why stretch it out, he thought? Just give him what he wants now. Maybe he'll choke on it. Jack pulled out three thick file folders.

"The proposal, eight years of progress reports, and three journal articles. There are other copies."

The gunman gave him that quizzical smile again. "That's nice." He waved the gun barrel again, toward the experiment bench.

It was like the gun was a "mouse" and Jack was the little arrow on a computer screen. He had to go where the hand willed. He felt powerless, like a woman in the hands of a rapist.

"Now let's see the business end."

"It's . . . in this vacuum chamber. I just finished a run. Perhaps you could look just through the observation window?"

Now the gunman laughed. "You may have thirty seconds left to live, but you don't want to waste a good pump-down. Ha! Fine. I want to see this mother work and I don't have time for another pump-down either. So, talk me through a diagram."

Jack did so, with the gun so close to his head that he could still smell the shot. But the picture of his tormentor was filling in. The man had to have worked in a lab at some time—it was in his language. He knew things.

"Finally," Jack concluded, "the three beams emerge into the mass spectrometer separated by about a microradian. That's tunable—the momentum detector port is fixed and I change the magnetic field until the beam I want to measure is bent by the correct angle."

"Yeah, that's basic. OK, now, show me how you do this. Every step. You won't be around to help when I . . . when my clients do this again."

That sounded pretty final. Of course, Jack's usefulness would end when the gunman had what he wanted. But the gunman wanted cooperation, and so allowed hope.

If one had to die, Jack thought, one should do it with dignity. That was the way it had been in the land of his ancestors.

Gina, I love you, I don't want to go. Not now, not this way.

"Let's get on with it." The man waved the gun back to the control station. "Boot it up."

Jack nodded quickly. "The software is still on. Artoo, activate program . . . no, just a minute."

If one had to die, one might as well see what one's apparatus could really do first. Radiation was beside the point, now. Gammas, neutrons, pions shooting right through the chamber walls, the pions decaying into the tightest beam of neutrinos this world had ever seen. He chuckled, inanely, to himself about seeing neutrinos—then stopped.

There were places where you *could* see neutrinos, and one of them was just a few kilometers around the bend of this tunnel—where Gina worked.

"Please excuse me," Jack said in a trembling voice. "I should not run that program again because of the radiation. We would both be sterile, I think. I need to be more careful."

"No shit! OK, you have ten minutes—after which you'll be trying to

do this on one leg. Understand?" The gunman grinned frostily at him again. But there was something eager in the grin, something beneath that hardened exterior that understood. The man must have been a physicist at one time, or at least a physics student. Where?

Here? Before they canceled the supercollider? It would explain how he'd gotten in and out, and been able to hide in the tunnels until Jack's experiment had succeeded. The gunman would have been a very young man then, Jack's age—full of dreams. Then they'd let everyone go.

Jack nodded and fumbled through the papers on the desk beneath the computer. There it was! The main evacuation diagram. It showed the neutrino observatory around the curve of the tunnel—sixteen kilometers of solid Texas rock. Sixteen kilometers of near vacuum, to a neutrino. He had to eyeball the angle and be very careful to disguise his purpose—the man watching him would know about the neutrinos.

He brought up the mass spectrometer control simulator and adjusted the magnetic field controls until the negative pion beam was headed in about the right direction.

"We're just about ready. I'm going to up the output a bit, enough to get some secondary fluorescence out of the annihilation gammas. That way you can see that it's really working."

"OK." The gunman was staring at the computer screen instead of Jack. Maybe if he was distracted enough. . . . "You know we . . . they were going to make antiprotons here back before. . . ."

Jack snuck a look at him; the man's eyes seemed to glisten for a moment. Then the moment had passed and the gun was leveled at Jack's head again. "Let's get on with it."

Jack nodded. Would just a steady neutrino signal be enough, he wondered? They might not look at their data for days. He should modulate it.

"Pulse mode," he said as he made the changes. Explain everything correctly, he told himself, but disguise purpose. "Keyed to the mouse, OK? Less radiation that way. I'm ready to start. If we turn the lights down, you should see flashes at the window."

"I'll take my chances with this light."

"OK. Artoo, activate program nine point three."

There was a slight snap, and the screen display showed only a slight signal. That was because the beam wasn't hitting the detector, deliberately.

"I didn't get the . . . the beam aligned quite right, so we're not seeing it on the screen as much as it should—"

"You're misaligned a bit for the detector, but I saw the flash! Hit it again. Enough antimatter to make a reaction I can see! That will show them. Thirty bloody years, damnit! And they told us it wasn't worth anything. You didn't hear that, kid."

Jack barely *had* heard him. He was thinking furiously, trying to imagine a message, oblivious to everything outside his own head. What kind of signal would Gina recognize? Jack didn't know any code—was "SOS" three dashes and three dots or three dots and three dashes? His finger was

poised over the mouse key when he spotted a cheat sheet with the physical constants he'd taped to the shelf next to the computer.

Ah—so. He started tapping the key. Six times, wait, six times more, wait, two, wait, six, wait, one, wait, seven, wait, six. That was “h,” Planck's constant.

“I see it, I see it,” The gunman said, his voice excited, not threatening. “Not too efficient, yet—you're getting some glow from the positron beam too, aren't you—on the left?”

Actually, it was the positive pion beam, but Jack didn't feel like correcting him. “Yes, but only a few. This is just an experiment; it—”

“I understand. Let's see some more. This is interesting, if it's this reliable already. You lucky son of a . . . Hit the key again.”

Trembling, his finger tapped twice, then seven, then once, then eight, two, eight again. That was enough for “e,” the base of natural logarithms. There was no “l” on his cheat sheet, but Jack had an answer to that, one that Gina would be sure to get. The universal gas constant: eight, three, one, six . . . finally, P? Ah, standard atmosphere pressure, in Pascals.

Then back to Planck's constant. He tapped slowly, as if at random, looking at the flashes of annihilation energy. He did not have to fake worry about the radiation.

“That's enough,” the gunman said by the time Jack had tapped his way back to “e” again. “Now, the most critical part of this setup has to be the collision chip, right?”

Jack nodded. “Yes, that was the

hardest to make.” Except for the software. There were eight months of work—trial and error nanolithography—in that millimeter-thin, square centimeter chip. It was unique in the Universe—the first and only one that had worked.

“Not hot, is it?”

Jack thought about saying yes, but he'd explained the beam line too carefully. The gunman knew that the meson and baryon beams emerged into the steering magnets without hitting anything.

“No. But it will take a few minutes to dump the vacuum—non-destructively.”

The gunman smiled wryly and waved at him again. “Get with it. You've got a briefcase here? With a security tag.”

The bastard *had* thought of everything, Jack realized. With a cleared case, he could take anything he wanted out of the lab, provided it would fit. Who the hell was he?

Jack told the computer to open the pressure valve, and found his briefcase for the gunman. Brown, pseudoleather, D.O.E. issue—at least that had no sentimental value.

It took ten minutes for the pressure to equalize in the collider chamber, and another ten to unbolt the flange. The liquid helium had already drained and evaporated, but the gold-plated box with the nano-channel chip and the field effect needles was still burning cold to the touch.

Jack ignored the pain, taking a perverse pride in his ability to do so. His ancestors would approve. Pain meant nothing now. He handed the precious

device to the gunman and allowed himself a momentary pleasure in the scowl on his tormentor's face as his fingers closed on his frozen booty. They would both leave skin on it.

"Be careful," Jack said, with cold irony, "It has not warmed to room temperature yet."

"Ouch! Now you tell me!"

It was like giving away a child. He'd used the scanning tunneling microscope needle as his waldo to place the last ten thousand atoms on the chip with a precision that he could not yet be sure a machine would match. There were no little bumps and clusters in those final layers—it was a perfect geometric arrangement—a continuous superconducting layer with deliberately asynchronous flux pins to prevent resonant quenching. He had bound it against its titanic magnetic pressure with a monomolecular fullerene belt. That had taken him six months to get right.

The man produced a small paper bag and dropped the device in it.

Jack shut his eyes. An end, he told himself, came to all things.

The man put the bag in the briefcase, with all of Jack's documents.

"There is no way I can talk you out of this?" Jack ventured.

The man shook his head and gestured with the gun again. "Move over there and face the wall."

There was about a meter of unused wall between the vacuum pump and the computer rack. Two-centimeter aluminum utility conduit tubes ran along it in a bundle at about waist level. Otherwise it was bare concrete. The last thing, Jack thought, that I will

see in my life. "May I leave a note for my fiancée?"

"We've been at this for three hours. If you haven't figured out how to do that, it's too late now. I let you play with your apparatus longer than I should. Once upon a time, I . . ." The man shook his head. "You've already done more than most people in a lifetime. Take that thought with you—but it's reality time now. Face the wall!"

"I could do more," Jack said, with as much dignity as he could muster as he turned. "If this science once meant something to you, let me live. Let me continue my research." There were a million undignified things he could do to try to rush the man and struggle with him. But they would all be ineffective—the man was at least twice his size and armed. Jack would not give him the excuse of self-defense.

He stared at the wall for what must have been a minute. Get it over with, he thought. Finally, he started to turn back.

"Don't! I don't owe this idiot world and its idiot people a goddamn thing!"

The man was so close, Jack could smell his breath and thought he could feel the cold of the gun. What was taking him so long? He almost felt like shouting "get it over with." But no. The man was clearly troubled—Jack's words must have had an effect. He was an intelligent man, who once had thought to dedicate his life to acquiring knowledge instead of money. The thing to do, Jack thought, was to let the gunman's conscience work for him, a kind of psychological jujitsu.

If Jack gave him no excuse, perhaps

he would not shoot. He had to take his mind away—to do nothing as hard as he could. He sought refuge in “the Kubota effect” and concentrated on the wall. He tried to imagine himself so small that he could climb inside the block, between the grains of concrete, and win his way through, then up through the soil into the bright sunshine above. The smell of the gunman faded from his mind.

He imagined doing this hand in hand with Gina—exploring the inside of the concrete block the way they were going to explore the Universe together, cataloging passages like neutron stars, doing papers on the stochastic properties of molecular bonding in Portland cement and the topological similarities between cement and the large scale structure of the Universe.

The bullet, when it came, would interrupt some very important work.

Sounds made their way to him. Somewhere, in the distance, or above him, he heard the whine of one of the electric carts they used to traverse the unused tunnel. Perhaps he and Gina could lay tracks for such carts through the pores of their concrete block.

An interesting endeavor, he thought. On the microscopic level there was a universe of passages in this one block—it would take a lifetime. Perhaps the way to approach it was with many machines, Von Neumann machines could do it, but they would have to be very tiny. Like his chip. He could use the same apparatus, with some modifications.

“Jack! Jack!”

“Gina?” For a crazy confused moment, Jack thought the voice came from the cement, but no, no. He snapped back to reality. How had Gina come so soon? She’d get shot! He yelled right at the block, sure that it would reflect the sound, and heedless of the consequences. “Gina! Get away! He’s got a gun!”

Then Jack spun around, hoping to draw the gunman’s fire to himself. But there was no one there.

Dark-haired Gina drove into his laboratory’s light pool from around the bend of the tunnel, left her cart in the center, and threw herself into his waiting arms. “Oh, thank God you’re all right! What happened?”

“Oh. Oh, Gina. Oh Gina.” That was all Jack could say. “Someone stole my plans and my chip, and our papers. I thought he would shoot me.”

“It’s OK, Jack. Whoever it was is gone. There’s no one here. It’s been half an hour since you signaled me.”

They held each other for long minutes. Finally Jack let out a long sigh and caressed her arms as he released his embrace. “He knew what he was doing. There was something about him, as if he were, for a moment, involved again in something he cared about. He was one of us once, I think, a scientist or an engineer, on the supercollider. But he’d fallen to this. And he was bitter about it. I made him wrestle with his conscience. I didn’t give him any more reason to shoot. But he stood there forever—it was like he couldn’t make up his mind about which world should live. Mine or his.”

“You’d never fall that far.”

"I think he was supposed to kill me." Jack shook his head. Entropy was gaining on the world above tunnels, these relics of an era when people could do things collectively. Now, the dogs were eating dogs, and people had to carefully avoid dogfights. Finally, he managed a smile. "When I am too old to fall in such a way, then I will judge him. What took you so long?"

"When we realized those were physical constants coming through, one of the grad students grabbed a C.R.C. and sat down with it for what seemed like forever." Gina giggled. "Finally he turns around and asks 'why would anyone send h . . . e . . . R . . . P?'"

"It must have taken me a minute to figure it out. But then I *knew* it was you, where you were, and that you needed help! I called security and headed for your lab."

There were other footsteps in the tunnel. Uniformed security guards appeared around the bend.

Gina put up a hand. "It's all right now—he's gone."

A lean, dark-haired security officer nodded. He was carrying Jack's briefcase. "We took this off of someone

without a valid badge; he had a thirty-year-old key that still worked. Unauthorized, of course. Yours?"

With a trembling hand, Jack reached for the briefcase and thumbed the combination lock. Inside was the paper bag with the small, gold-plated box that contained his life's work. He shut his eyes and bowed his head briefly. He knew now that he could leave that life with dignity. But, fortunately, not just yet.

Jack nodded to the officer. "The man who was carrying this?" he asked.

"He surrendered and asked for protective custody. Says he's doing 'research' for the Myanmar government and wants to quit." The guard looked Jack in the eye. "He had a Berretta nine millimeter on him—fired recently."

Jack gestured to the punctured file cabinet. Then the tension of the last hours escaped him and he collapsed into his chair with an audible groan. Gina rushed to help him.

"Mr. Kubota, are you all right?" the security officer asked.

"Just tired." Jack put his right arm around Gina and gave the man a big grin. "As rong . . . long as this lady loves me, I am just fine." ■

MOVING?

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THE "REAL WORLD" AND THE STANDARD MODEL

The hot news in particle physics last year was the March 2, 1995 announcement that the top quark (or Top) had been discovered and its mass measured by the CDF and D0 proton-antiproton collider experiments at Fermilab. The Top had been a missing piece in the particle physics jigsaw puzzle. The Top, the heaviest of the six quarks of the Standard Model, had been predicted and its discovery expected for several years, but the measured size of the Top mass came as a big surprise.

Before the Fermilab measurements, the "smart money" was betting that the Top would have a mass around 120 GeV. (Here using $E = mc^2$, we give mass in energy units. For reference, a proton has a mass of 0.938 GeV.) The Fermilab measurements indicated a Top mass of about 180 GeV. Theorists are still agonizing over the meaning and implications of this larger-than-expected mass for the heaviest quark of our Universe.

But the question raised repeatedly in the news media was, what difference did it make? Who cares whether

the Top mass is 180 GeV or 120 GeV? What possible effect could it have on the "real world" of Medicare and rock stars and ethnic cleansing and superbowls and insider trading? In this column we will present some ideas from a colloquium given recently at the University of Washington by Dr. Robert N. Cahn, of Lawrence Berkeley National Laboratory, which address that question. We'll start by considering the Standard Model of particle physics.

The Standard Model is the physical theory that embodies our current understanding of the microcosm. It uses as particle building blocks the six quarks (down, up, strange, charmed, bottom, and top), the six leptons (electron, mu, tau, and their respective neutrinos), and the mediating particles that generate the four forces of nature. There are 14 mediating particles: eight color-carrying gluons for the strong force, one photon for the electromagnetic force, three "left-handed weakons" W^+ , W^- , and Z^0 for the weak force, and (perhaps) one graviton for the gravitational force.

The Standard Model describes the interactions between these particles in terms of four constants which characterize the strengths of the forces and four coupling constants which indicate the ease with which one quark can be converted to another by the weak force. In addition, it describes the "unification" of the strong and electro-weak interaction at sufficiently high energy and invokes a massive Higgs boson and a related strength constant to accomplish this.

The Standard Model is very frustrating for those of us who want to gain a deeper understanding of the Universe by finding places where our current understanding fails. On the one hand, the Standard Model provides remarkable predictive power. At this writing there are no experimental results in serious conflict with its predictions. On the other hand, the Standard Model is based on the values of about two dozen adjustable parameters: the particle masses and the strength and coupling constants. If we ignore gravitation and set all neutrino masses and "right-handed" weak interactions to zero, there are 18 remaining parameters. We have no real understanding of where these 18 numbers come from or how they might be connected. We are stuck in this present state of knowledge because we have not yet found a way to "break" the Standard Model (as relativistic and quantum effects "broke" Newtonian mechanics) so that we can gain understanding of underlying mechanisms.

Nevertheless, the predictive power of the Standard Model permits us to explore how the Universe might be

different if the parameter values were changed. This was done by Robert Cahn in his colloquium. It is an exercise that gives interesting insights into how the real world would be different if the parameters of the Standard Model had different values. We'll present some of Cahn's scenarios here.

Scenario 1—Increase m_{up} : In the Standard Model, the down and up quarks have masses of about 10 and 5 MeV, respectively, and the mass of the neutron (2 down quarks plus 1 up quark) exceeds the mass of the proton (1 down quark plus 2 up quarks) by 1.3 MeV. Suppose we increase the up quark mass by 2.6 MeV, so that the proton becomes *heavier* than the neutron by 1.3 MeV. What kind of universe would result?

If the proton were heavier than the neutron, all free protons in the universe would become radioactive and decay into neutrons by the emission of a neutrino and a positron. The normal matter of the universe would consist of neutrons, electrons, and positrons.

The gravitational attraction responsible for the formation of stars and galaxies in our Universe would still be in effect, but the stars that formed would be neutron stars from the outset and would have qualitatively different stellar dynamics. Fusion, combining four neutrons to form a helium nucleus would still take place, so the neutron stars would be luminous. However, since no electrical repulsion would inhibit the fusion process it would proceed much more rapidly, and much smaller stellar masses would be able to achieve fusion and

become luminous, and these also would burn out and produce supernovas more rapidly.

The synthesis of heavier elements, if there were no blockages arising from the altered masses and level structures of nuclei, would perhaps be possible, but the "valley of stability" of the resulting elements and isotopes would be shifted toward more neutron-rich elements. For example, carbon-14 would become a stable isotope, with the result that nitrogen-14 would be radioactive. It is questionable whether life could exist in such a universe. At minimum, the "real world" in that universe would be very different from our present one.

Scenario 2—Increase m_e : In the Standard Model there are three generations of charged leptons, the electron ($m_e = 0.511 \text{ MeV}$), the muon ($m_{\mu} = 106 \text{ MeV}$), and the tau ($m_{\tau} = 1784 \text{ MeV}$). Suppose that the muon was the lightest charged lepton (or equivalently, that the electron's mass was 207 times larger so that it had the mass of a muon). What kind of universe would result?

First, all atoms would be 207 times smaller because the Bohr radius of an atomic orbit is inversely proportional to the electron mass. Second, electrons would be bound to atoms 207 times more strongly because of the smaller orbits, and the photons produced when an electron moves from one atomic orbit to another would be more energetic by a factor of 207. Visible light from atomic transitions would be shifted into the x-ray region. Third, the time scale for atomic processes would also be increased by

factor of 207. However, the speed of light itself would be unchanged, so atoms would show more effects of relativity.

One might think that in this heavy-electron universe the universe would be a nice compact environment. If all the atoms of our bodies were scaled down together, biochemistry would work as usual, and we would not even notice the change. Everything would fit into a smaller space, with lots of energy and with atomic and biological processes progressing on "fast forward." Very efficient. However, there's a hitch.

In our Universe a negative muon has a high probability of being captured by an atom. If captured, it rapidly moves to the innermost atomic orbit, where its orbit brings it inside the nucleus with a high probability. In less than a microsecond the atomic nucleus captures the muon, changing a proton to a neutron in the process and spitting out a muon neutrino. The resulting nucleus has one less proton, one more neutron, and may be radioactive.

This same process would occur with the electrons in our heavy-electron universe. Both neutrons and protons would be stable particles, but all atoms (charged nuclei with orbiting electrons) would be unstable to electron capture that would reduce the nuclear charge with each capture. This capture process would cumulate in the reduction of all matter to neutrons and electrons. There would be no stable atoms, no chemistry, no biology, and therefore no life-as-we-know-it.

Scenario 3—Only one generation:

In the Standard Model there are three generations of leptons and three generations of quarks. Suppose that only the “middle” generation, the muon, its neutrino, and the strange and charmed quarks, existed. What kind of universe would result?

In the first generation of quarks in our Universe, the up and down quarks have masses that are very close in energy. This is not true for the second generation. The charmed quark has a mass of about 1,500 MeV and the strange quark has a mass of about 150 MeV. Therefore, there will not be any stable particles containing charmed quarks. Therefore there will be no neutron-like or proton-like stable particles which are a combination of the two quark flavors, and consequently no stable complex nuclei. The middle-generation universe will contain only two stable particles, muons and omega baryons which are a combination of three strange quarks. The omega would be the only stable nuclear-mass particle in the universe. All the atoms in this universe will be hydrogen-like, with muons orbiting omegas. If stars form from these mu-omega atoms, there will be no fusion or nucleosynthesis because there are no other nuclei.

Scenario 4—Decrease m_{top} : The top quark according to the recent Fermilab measurements has a mass of about 180 GeV. The other member of its generation, the bottom quark, has a mass of about 4.5 GeV. Suppose we drop the top quark mass by a factor of 10 to 18 GeV. What kind of universe would result?

The force constants of the Standard Model are not really “constants,” but rather indicate the force strengths in the low energy limit of our “real world.” The strengths of the forces of nature vary with energy, and at sufficiently high energies all the forces have the same strength. Thus, the true force strengths are set at very high energies and evolve downward as the energy is dropped. The evolution of the force strengths occurs because in an interaction process more varieties of virtual particles can be created at high energies than at low. Therefore, the masses of the virtual particles affect their participation and determine the resulting force strength in the low energy limit.

Cahn calculates that if the top quark had a mass of 18 GeV instead of 180 GeV, the resulting evolution of the electromagnetic interaction would be to decrease its low energy strength by about 0.5%. All electrical forces would be weaker by one part in 200. The rate of fusion reactions in the Sun is proportional to the reciprocal of the electromagnetic strength constant to the 9th power. A 0.5% decrease in electromagnetic strength would result in a 4.5% increase in energy production in the Sun. Curiously, this would not increase the solar temperature but the solar radius. The Sun would swell and appear slightly larger in the sky, and as a larger object at the same temperature, it would deliver more solar energy to its planets.

Cahn also showed that a Top mass of 18 GeV would reduce the strength of the strong interaction, and this would reduce the masses of the pro-

ton and neutron, because their masses primarily arise from strong interaction gluon effects rather than the up and down quark masses. He calculates that the neutron and proton, with the up and down quark masses held at their Standard Model values, would be decreased in mass to 87% of their "real world" values.

In the "real world," chemical and biological processes would be affected by a weakening of the electromagnetic force (and therefore chemical bonding) and by reduction in the masses of atoms. The drop in neutron and proton masses would also effect nuclear reaction and decay processes, particularly radioactive decay and nuclear fusion. It would shift the positions of energy levels in nuclei, and this might inhibit the synthesis of heavy nuclei in stars. It is very difficult to assess the overall effect of these changes, but it should be clear that in a universe where the Top mass was a factor of 10 smaller, things would be very different in the real world.

Our present Universe, which depends in subtle but important ways on the values of the Standard Model parameters, works very well the way it is. As we have seen, most variants involving parameter changes lead to unpleasant results. By what process were the Standard Model parameters set to the values that we measure and that produce the life-sustaining "real world" in which we live?

I wish I knew. ■

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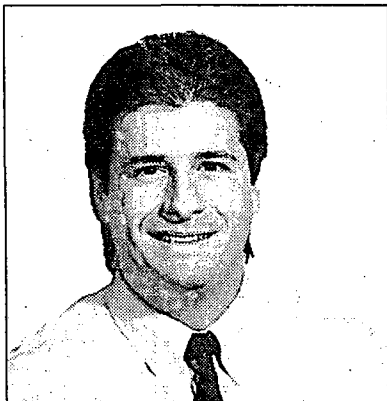
In 1939, at the first world science fiction convention, the guest of honor was an artist. A half-century later, *Analog* cover illustrator George H. Krauter continues the tradition of enchanting SF readers with a slice of imagination made real. In the 1920s and beyond, Frank A. Paul presented an up-to-date-ultra-modern look where men had brush cuts and women wore bobbed hair matched to equally short and daring skirts.

That very first SF artist had to contend with contemporary technology, which he told me required putting the brightest possible pigments on his brushes so that printing presses and pulp paper wouldn't gray-down the art. Presses have improved along with paper but use of brushes dating back to antiquity have remained standard, along with air-brushing techniques now a couple of generations old.

George is getting a jump on the 21st century with computer-generated art. He did the first *Analog* cover and probably the first fiction magazine cover anywhere in that medium for the May 1994 issue. Art directors are generally matter-of-fact about the artwork crossing their desks, but *Analog*'s Terri Czczko declared George's cover "stunning." Fast new computers with innovative high-grade printers and sophisticated programs offering previously impossible shading

algorithms opened opportunities for a young artist who grew up with science fiction.

George earned his BFA at Stony Brook, SUNY, where he participated in the university's annual giant SF convention. He had attended a New York



George H. Krauter

City high school that centered around art and music. His first work for *Analog* was an interior in the January, 1993 issue. Moving last year to San Francisco, he found animation another natural field for a computer-literate artist. His first commission was for Larry Niven's *Ringworld*.

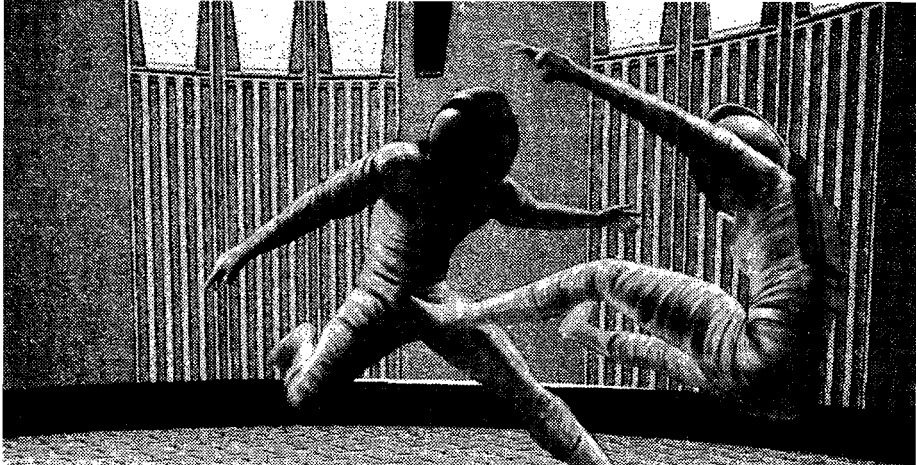
Terri has been impressed by George's highly detailed and accurate spacescapes. After reading a manuscript, he works up roughs, followed

(Continued on page 152)

Let's go to
the store. You
can buy a
lot of things
there.

E BEEN WANTED





Conclusion

Charles Sheffield & Jerry Pournelle

HIGHER EDUCATION

*The most important lessons aren't
always in the curriculum. . . .*

Illustration by George H. Krauter



SYNOPSIS

Rick Luban is a bored sixteen-year-old trapped within an education system that does not care if he succeeds or fails. He is learning next to nothing, and his teachers lack all authority over their students.

Rick is expelled from school when a practical joke on a new teacher backfires, and catches instead a visiting congresswoman. Afraid to go home to his mother and stepfather, he is sitting outside the school when he is approached by one of his teachers, **Mr. Hamel**. Hamel feels some sympathy for Rick, and suggests where a job might be available.

Rick takes a battery of aptitude tests, and passes. He is offered a trainee position with Vanguard Mining and Refining. However, the job is not on Earth. Rick will be trained to mine the Asteroid Belt, out between the orbits of Mars and Jupiter. First, though, there must be training on Earth. The very next morning Rick has packed his few belongings and is on his way to New Mexico.

He quickly learns that his new job is going to be competitive. Not every new recruit will make it to the end. After a hard few weeks Rick learns that he is through the first phase, along with **Alice Klein**, **Chick Teazle**, and Rick's sworn enemy **Vido Valdez**, with whom he has already had one fight. On the flight up from the surface of Earth Rick meets another adversary: **Deedee Mao**, a tough and aggressive girl from a different training camp. They get into an argument, which ends abruptly

when they encounter free-fall for the first time.

As their ship approaches **CM-2**, **Jigger Tait**, an experienced space miner who is on his way back to the Asteroid Belt from Earth, points out something else that no one has told Rick and Deedee before: Vanguard Mining has competition. There is another company, **Avant Mining**, aggressive, fast-growing, and a real threat to Vanguard. Jigger shows them an Avant Mining ship, returning from the Asteroid Belt.

Once the recruits are installed on **CM-2**, the next stage of training begins under **Turkey Gossage**. The true nature of the authority exercised by Vanguard Mining becomes apparent: students will not be forced to perform their assignments; but only if they do so will they receive meal tickets for food that is worth eating. Otherwise it will just be oatmeal and vitamins.

With no real choice, the new recruits settle down to work. They must learn to read and write well, and know enough mathematics to solve practical problems important in space mining. Rick feels that he is doing pretty well, until one day he makes a dreadful mistake. After one of his practical tests he puts a sexual move on **Gina Styran**, Turkey Gossage's attractive assistant. However, she can look after herself, so effectively that Rick is convinced that he is permanently injured. He limps away to the **CM-2** gymnasium, where he meets Jigger Tait and learns something even worse: Gina is Jigger's girlfriend, something that

Rick had no suspicion of before.

Fortunately Jigger seems more amused at Rick's nerve than upset by his act. He tells Rick that Gina only looked at him in a friendly way because he reminded her of her own kid brother, back on Earth. As for Gina herself, she never bothers to mention the incident to anyone.

Soon Rick has something to take his mind off his gaffe with Gina. Vido Valdez—wrongly—thinks that Rick has made a play for his girlfriend. Actually, Rick has just been trying to help her with her math homework, which gives her special difficulty, but Vido doesn't want to listen. They have another fight, which Rick wins because he has been working out regularly in the gym with Alice Klein. He knows how to move in free-fall better than Vido, and knocks him unconscious.

The next morning Rick is summoned to see Turkey Gossage. He thinks he is in trouble, but learns to his surprise that Vido has told Turkey that the fight was his fault. Turkey wants to see Rick about another matter: his final practical test, for which he has been paired with Deedee Mao.

Deedee and Rick do not get on well together, but Turkey does not offer them a choice. They have to load an ore carrier, take it to the CM-2 refinery, and return—with a tight deadline. As they set to work they find that Turkey has built in extra problems, things that will go wrong at every stage. They struggle through loading oddities, drive failures, and doors that are locked when they

should be open. Their final difficulty, however, defeats them. They cannot complete the trip outside CM-2, because of an intense solar flare.

They do their best, making part of the return journey inside CM-2, and the rest shielded by the mine's bulk. But they reach Turkey Gossage after their deadline, convinced that they have flunked.

Turkey tells them that the solar flare was an accident, not part of the test at all. They have actually passed their practical beyond his expectations. All that remains is the final theory paper.

A few days later they struggle through that, and after a tense waiting period Rick and Deedee learn that they have passed, along with Alice Klein, Vido Valdez, and Chick Teazle, plus Lafe Eklund, Goggles Landau, Gladys de Witt, and Polly Quint.

There is a final celebratory party, where Rick dances with Deedee for the first time. Then they head for the Asteroid Belt under the direction of a tough, no-nonsense training director called Barney French. She makes it clear that things are not going to be easier than on CM-2—in fact, they will be harder. The recruits must learn how to ferret out for themselves the information that they need, using the data banks.

Barney doesn't believe in helping them, but if they want to they can help each other. So it's no big surprise when Alice Klein turns up in Rick's cabin, asking for assistance with a tricky orbit problem. More of a surprise is the really neat solution

that Rick and Alice come up with together. And more surprising yet is when, with the problem solved, Alice takes the initiative and she and Rick become lovers.

Alice says they must keep their affair a secret, or it will hurt their chances with Vanguard Mining. But Deedee senses what has happened, and seems to want to talk to Rick about it. Before she can do so an emergency arises. There has been a bad accident on Company Mine 31. The ship heads there, and the raw recruits are called on to help. It is a grisly experience. When the trouble is over, a ship from Avant Mining arrives and offers assistance. It is angrily refused. Jigger Tait says the Avant Mining people didn't come to help, they came hoping to claim the ruined mine equipment as salvage and learn Vanguard's technology secrets.

The recruits arrive at last at their original destination, CM-26. They are all feeling pleased with their performance during the accident, and after they have examined the mine and smelting operation at CM-26 they decide that they should not have to go back to routine training.

They send a deputation of Rick, Deedee, Chick Teazle and Polly Quint to see Barney French. She quickly cuts them back down to size. She tells them that they have a long, long way to go before they can call themselves qualified mining engineers. She lists some of the things they still don't know how to do, and tells them that some of them may never make it through to the end.

And with that she kicks them out. It is clear that the hardest part of the training program still lies ahead.

Conclusion

CHAPTER FIFTEEN

Rick, like the rest, felt crushed and humiliated by Barney French's anguished putdown. It took Alice Klein to offer a different perspective on what was really happening.

"You know what they've been telling us since day one," she said. She nudged him with her elbow to get his attention. "*Things are not what they seem. Expect zingers.* I bet that's what is happening now."

She was snuggled at Rick's side, naked in the darkness of his cabin. It was two days after their arrival at the new training facility, and until now the whole time had been non-stop effort—mostly mental work, which Rick found far more demanding than physical labor. He had spent all day struggling with the unfamiliar notion of moments of inertia. According to the learning machines, moments of inertia were related to advanced methods of ore melting and metal extraction. It was hard to see how, and the problems he had been assigned did not help.

A strong and solid hoop is spinning around a massive central point to which it is connected by thin strings. All those strings are cut at once. What will happen to the hoop, and why? Comment: When you understand the answer to this question, you will know how the great Scottish physicist, James Clerk Maxwell, proved that the rings of Saturn can-

not be solid but must be made up of small independent particles.

Rick had about as much interest in dead Scotsmen as Maxwell had in him; but he did have ambition. He wanted to be a success in Vanguard Mining, and visions of a solid hoop spinning around and attracted by a central mass had plagued him all day. After the excitement and horror of the CM-31 disaster, going back to the old routine seemed boring; but he could not get his mind off this particular problem.

Spin the hoop, cut the strings. And then what? What would it do—still spin around the central mass, or something else?

He had been drowsing, his mind filled with rotating rings, when Alice spoke again. "Did you hear me?"

"Uh-huh." He grunted his reply. She was supposed to interpret that as meaning, hey, sex was really terrific, but now I'm much more interested in sleep than conversation.

She nudged him again. "I checked the qualities that successful apprentices are supposed to display." Alice's long, thin limbs were much stronger than they looked, and lovemaking just seemed to fill her with new energy. "Do you know what the most important quality is, according to the manuals?"

"Intelligence?" *A strong, solid hoop.* That meant it was able to stand either compression or tension. As he had learned long ago, the assigned problems did not tell you things that you didn't need to know. And gravity had to be important, too, because the central point was stated to be mas-

sive. The hoop and the central mass would attract each other.

"Wrong." Alice wriggled closer. "You only say it's intelligence because you think you're smart. The most important quality isn't knowledge, either. It's *initiative*. But it seems to me that initiative is the exact opposite of doing what you're told and following somebody else's instructions."

"What are you suggesting? That we ignore our assignments? Then we flunk everything and get kicked out."

"No. I think they want us to try things for ourselves. They want us to push the envelope, keep going as far as we can until we're stopped. Unless we're told not to go somewhere, we should make a point of checking it out. Unless something is forbidden, we go ahead and do it."

"Mmm."

"Agreed?"

"Uh-huh."

So far as Rick was concerned that was the end of the conversation. He didn't remember any discussion after that. On the other hand he didn't even remember Alice leaving his cabin. Her words went forgotten until three days later, when the whole group of apprentices was told to put on their suits and assemble inside the Smelting Module.

That was the official name, usually shortened to "the SM," for the cylinder that Lafe Eklund had dismissed as a "toy" the first time that they had seen it. Close up, the SM seemed anything but a toy. Access to the interior was gained through an elaborate triple hatch, more complex than any that Rick had ever seen before. It was

located near the edge of the SM's flat circular end, and its three octagonal doors had to be passed through in series, one after another. Each chamber had a little side room with its own door, and every door had a central viewing port of thick transparent glass. From any part of the lock, and even from outside it, you could see all the way along the axis of the cylinder to the other end. That other end was partly open, showing beyond it a disk of star-filled open space.

The size of the Smelting Module was even more apparent once you were inside. Rick, passing through the lock, found himself in a gigantic empty room that towered twenty times his own height. The inner surface of the curved wall was bare, blackened and crusted with hardened ore residue and dross. The flat end of the cylinder through which Rick had entered was covered with instruments, equally dark with dirt and battered as though with long use.

Since they were in free fall it was easy to soar from the "bottom" where they had entered up to the "top," and peer outside. Most of them did that. They saw half a dozen small asteroids, just a couple of kilometers away, co-orbiting with the SM and with the main body of Company Mine 26. They could also see that this end of the SM was made up of flat interlocking sectors, so that the whole end could either close completely or iris wide open. Like CM-31 but on a far smaller scale, the SM could stretch its maw wide enough to engulf any one of the waiting asteroids.

"All right, that's enough boggling at

nothing." Barney French, down at the bottom of the SM, clapped her suited hands together from habit. It produced no sound at all in hard vacuum, but they heard her call through their suit radios: "Let's get down to business."

For the past few days she had been in her toughest and most sarcastic mood, as though she wanted to deny that she had ever displayed any sign of sentiment or human feeling. That had made the returning deputation's job doubly difficult when they went back to the dining area after their meeting with her. None of the other apprentices believed that Barney was capable of softness, and they had suspected Rick, Deedee, Polly, and especially Chick of being afraid to make their case. Even Alice seemed skeptical when Rick repeated to her what Barney had said during the meeting.

He stared across at her now, floating over at the other side of the group of apprentices. Within her suit visor, Alice's icy grey glance passed over Rick, roamed over Vido Valdez standing next to him, and continued on to stare calmly at nothing.

No one would ever guess what she could be like in private. But Rick didn't have to guess. He had absolute personal proof. He tried again to catch Alice's eye, and was rewarded by what might have been the faintest of frowns. She would probably give him hell for that later, but he didn't care. It was her fault for avoiding him for the past few days.

"Now use your brains if you have any." Barney's voice in Rick's headphone brought his attention away

from Alice. "You may wonder," she went on, "why we came in through that odd triple hatch. What is its purpose? Did any of you happen to have your eyes open when you came in, or is that too much to hope for?"

She sounded like she was in a savage mood. It was Goggles Landau—always sensitive to any suggestion that he might not see as well as anyone—who risked ridicule.

"It's not just a hatch," he said. "It's an airlock, too."

"Indeed it is. But when smelting begins, anybody inside the SM wouldn't last two minutes. Would you like to take the next step, and tell me why a smelting facility needs an airlock?"

Rick was just a couple of people along from Goggles and could see his face through the visor. There was a mortified look there that said, *Trapped! Why didn't I keep my big mouth shut?*

Rick didn't feel much sympathy. Hadn't Goggles learned the basic rule back in kindergarten? *Never volunteer: The nail that sticks up gets the hammer.*

And sometimes the nail that doesn't stick up gets it, too. Because Barney was saying, "You do not know, Landau? Then how about you, Luban? That smarmy grin on your face suggests you are feeling highly pleased with yourself. So you tell me why SM needs an airlock."

Another rule, one that Rick had learned more recently: On a test, any answer at all was more likely to be right than no answer at all. He tried the obvious. "It has an airlock so that if the top end of the SM were closed,

the inside could be filled with air."

"True, but hardly an earthshaking conclusion. You are evading the real question. *Why* fill the SM with air? Air would be nothing but a nuisance during smelting."

Rick cast his eye around the interior for inspiration, and saw the grimy and blackened instruments on the flat end of the cylinder. "You fill it with air so that crews can work in here. For— for maintenance."

"Close enough. Of course, maintenance crews could work very well in suits. But I'll accept your answer, because I doubt that any of you could get much closer." Barney looked away from Rick, to his huge relief, and addressed the whole group. "The right answer is, the airlock was put here for *you*. The airtight interior of SM exists for your benefit, and for the benefit of past and future apprentices. I hope you are suitably appreciative.

"This is a real live smelter, although a small one, but it's also intended as a training facility. To this point, you've worked alone or in pairs. Now it's time for a practical effort where you will all work together. That's easiest done when you don't have to wear suits. In the next two weeks we—or rather, you—are going to do three things. First, you are going to clean all the muck out of the SM. Be prepared to eat your meals dirty and go to bed dirty. Second, once this place is clean you are going to learn how each instrument works. You are going to take them apart and put them back together until you can do the whole thing blindfolded. And third—the big scary treat—you'll get into your suits, go

outside, and work together to bring one of those waiting asteroids in here. You'll melt and centrifuge and tap, and when the molten metal flows I guess you'll feel like genuine miners. And *then*, assuming that goes well, you'll advance to Level Four—and be ready for something difficult. Any questions?"

This time everyone had enough sense to keep quiet. Barney nodded.

"Very well. You are free to make your way back to your quarters and continue with regular assignments. I will post a schedule for SM cleaning and maintenance later today, and work will begin here tomorrow."

She turned and led the way back through the triple-locking hatch. Rick was all set to follow with the others when Alice turned to look directly at him and jerked her head inside her suit. He hung back and waited, until just the two of them were floating in the cavernous interior of the smelter. She gestured to him to turn off his suit radio and moved so that their helmets were touching.

"What?" He knew she would hear him through their direct contact, although no one else would even if they were only a foot away.

"Remember what we agreed? If it's not forbidden, we assume it's permitted. Barney said we were free to go back, but she didn't say we had to. Let's stay and have a look around this place."

Rick had seen as much of the SM as he wanted to. The chance of finding a cozy place where he and Alice could snuggle up and have some fun was as low here as you could get. He wanted

her back at the main station, and into his bunk. But he couldn't tell her that, because she had already broken the contact between their helmets and was soaring up toward the other end. He trailed along behind, staring with no relish at all at the SM's crusted sides. In another day or so he would be scraping that crud away—and for what? So that they could melt down an asteroid, and make the whole smelter dirty again.

Alice headed to the very top, out of the open end of the SM and into open space. He followed her, and for the next minute or two they simply hovered, side by side. Rick stared around him, subdued by what he saw. Space felt quite different in a suit than when you looked at it through an observation port. The Sun was far off and small, a brilliant shrunken disk to his lower left. Close to it he picked up Venus and Earth, distinguishable from each other only because Venus was brighter and a little whiter. From this distance you would never know that the two worlds were so different, one bursting with life, the other a dead inferno.

Alice apparently had no interest in surveying the Solar System. She was studying the way that the whole top of the smelter could either open wide, or be closed completely to provide an airtight seal. She moved close to Rick and placed her helmet next to his.

"You know, this end could operate as an emergency exit if it had to. There must be control panels, inside and out. I bet that's the external one, under that plate."

Rick had been scanning the starscape for other planets. Mars and Jupiter were easy, but he had not been able to find Saturn. The biggest thing in the sky was the lumpy ovoid of CM-26. From this distance, it and the smelter were the dominant features of the whole Solar System.

He brought his attention reluctantly to the feature that Alice was pointing out. It was a white plate, small and almost insignificant, at the extreme outer edge of the flat circular end. Rick could see the big segmented plates that retracted as they opened, into a thick annulus. The white plate sat on the fixed outside edge of that annulus.

"Let's take a look at it." Before Rick could object Alice again had moved away and was zooming down. By the time that he joined her she had the plate cover open and was studying what lay beneath.

Rick put his head next to hers. "Alice! Don't you think—"

"Nothing to it. See." She directed the flashlight in her suit at one part of the exposed panel and placed a gloved finger on a pair of switches. "Here's the control to open the end of the SM, and here's the safety. This sensor tells you if there's air pressure inside the SM—that light goes on—and if there is, the command to open is automatically canceled. You'd have to override that manually, if you ever had reason to, and set this timer so you could get away before it opened. But how do you close it?"

Rick had been examining the rest of the panel while she was pondering the controls to open the SM.

"Like this," he said. He pointed out

another pair of switches. "This moves the plates that seal the end. No need for a safety to test for air pressure, because when the end of the SM is open there can't be any air inside. But there is an obstruction safety, here. The end won't close if there's anything standing in the way. That's so you can't destroy the plates by asking the end to close when an asteroid or anything else is sitting between them. Agreed?"

"Looks that way to me. Let's give it a try and see if we are right." She reached across Rick and placed her finger on the first switch that he had pointed out.

"Wait a minute!" He put his hand on top of hers and lifted it away from the panel. "You're not proposing to close it."

"Yes, I am."

"Don't be ridiculous. You can't do that."

"I don't see why not." She turned so that their visors met, and Rick was looking straight into those calm grey eyes. "If it's not actually forbidden—and nobody told us we couldn't experiment out here—then we assume that it's permitted. Isn't that the deal we made?"

"Within limits. I mean, you might as well say we could blow up the whole station and kill everybody, because nobody told us that we couldn't."

"Now who's being ridiculous? There's nobody inside the SM, and there's no asteroid anywhere close by. We can't hurt ourselves, and we can't hurt the equipment. I'm sure it's designed to prevent its own damage. Even if we're wrong we'll have done no harm, and if we're right we'll have

learned something that I bet none of the others will ever think of." Alice placed her finger again on the switch. "And we're showing *initiative*. That's the name of the game for the rest of our training."

She operated the switch.

Rick thought for a moment that he had been wrong about the controls, and nothing was happening; then he saw that the massive silvery segments bounding the periphery of the cylinder were moving, steadily shrinking the size of the circular aperture leading to the interior. The whole operation seemed uncannily smooth and silent, until he realized that any sound of metal moving over metal would not carry to him unless his suit was somewhere in contact with the surface of the SM.

The dark opening shrank and shrank, like a black pupil in a silver iris, until at last it was gone completely. The end of the cylinder formed a flat continuous plate, nearly forty meters across. Rick moved closer, seeking the invisible places where the sectors joined. Alice was still over by the control panel, studying it again. She touched one of the switches and the silver eye began to dilate, metal sectors rolling ponderously back until the aperture was as big as when it started.

Alice came floating across to Rick, grabbed the arm of his suit, and put their helmets together.

"We were exactly right. There's just one thing I can't figure out. Do you see any control that can fill the SM with air from this end?"

They wandered together back to

the control panel and Alice waited while Rick made his own examination. At last he shook his head.

"It looks like the air-fill has to be done from the other end. That makes sense. It's where you'd expect the pumps and air supply to be located. This can serve as an emergency exit, but it's not the usual way in."

"I suppose you're right." She touched Rick's helmet. "Radios on. Talking like this is a pain."

Rick agreed—with relief. The end to radio silence meant they must be finished with unauthorized exploration. "Ready to go back now?"

"Might as well. See, I told you that nothing bad would happen if we explored on our own." She grinned at him as they floated together past the outside of the smelter and headed for the main body of CM-26. For someone usually so unemotional she sounded vastly pleased, even excited.

Rick had more proof of that when she added, not quite casually, "We've done a pretty good day's work. What do you say to some R&R now—just the two of us?"

Some people, he thought as they passed through the main airlock and began removing their suits; some people got their hormones pumping in pretty strange ways.

CHAPTER SIXTEEN

Thanks to one sort of exploration or another, Rick had lost track of time. When he floated into the dining area for his evening meal he wondered why other people were already eating their final course.

Alice was sitting in the middle of

one group, relaxed and smiling. She ought to feel as dead and drained as he did, but if so she showed no sign of it. She was talking to Lafe Eklund, and she didn't even glance Rick's way when he entered the room. Rather than going over in her direction he went to another table, where Vido Valdez, Deedee Mao, Polly Quint, and Gladys de Witt were arguing vigorously. They hardly registered his arrival. Rick settled in next to Polly Quint. She was carefully polishing her nails, and he had the random thought that she was going to love scouring out the inside of the smelter for the next week or two.

"The question isn't *when*," Vido was saying. "It's *who*. Is it just another competition? And if so, what are the ground rules?"

"Grow up, Vido." Polly liked Vido, and showed it by putting him down. "You know they won't tell us—they never do. Maybe there are no ground rules."

"Then how will they decide?" Vido frowned at the others around the table. "I mean, none of the things that we've done so far has anything to do with this. So how do they?"

He stared at Rick as though expecting an answer. Rick, in a dreamy daze, paused with a fork halfway to his mouth. He had suddenly realized that he had no idea what they were talking about.

"Do they what?" he said.

"Rick!" said Deedee. But Polly gave him a more useful answer.

"Do they decide which ones of us—if any—will get to go." And then, when Rick sat open-mouthed, "As ju-

nior crew members. It's a big swindle. We've had hardly any assignments involving the moons of Jupiter. You'd think that if any of us was going to be involved in mapping and mining them, we'd have been better prepared."

It was dawning on Rick, far too slowly, that there had been some sort of major announcement and he had missed it. "I know quite a bit about the moons of Jupiter," he said slowly. "At least, I know a lot about the big four. I've had three assignments involving Io, Europa, Ganymede and Callisto."

"Which gives you a real leg up," said Gladys scornfully, "given that the exploration team will concentrate specifically on the minor moons: Leda, Himalia, Lysithea, Elara, Ananke, Carme, Pasiphae, and Sinope. What else do you have going for you, Professor?"

Rick decided that it was time for him to shut up, listen, and hope to learn what was going on. By the time that the others were finished and ready to leave, he had managed to piece it together. A new remote survey technique had been developed, capable of detailed analysis of distant objects. The results, still confidential within Vanguard Mining, were startling: the *smaller moons of Jupiter*, farther out from the planet than the major four, were formed of unique combinations of metals and hydrocarbons. Their value was incalculable. Vanguard was planning a major new initiative to send out a prospecting ship and stake mining claims. It would be a groundbreaking mission,

since the Jupiter system was unknown territory. It had been explored to date only slightly and superficially, by pilotless probes.

The whole project was a thriller—but a much bigger thrill was the rumor, sweeping through the group on CM-26, that three apprentices might be included in the team in addition to the seasoned miners and prospectors.

"But it's still *might*, not *will*," Polly said. Everyone from the other tables had already gone, leaving just Vido, Deedee, Gladys and Rick as her audience. "Apprentices *might* be chosen to go. Three of us may get lucky."

"That's good enough for me," said Gladys. She stood up from the table. "I don't know about you people, but from now on I'm a reformed character. No binges, no partying, no screwing around, private or otherwise. I'm going to work my tail off—no cracks from you, Vido—and be on my best behavior until further notice. Can you imagine it, being one of the first humans to explore the moons of Jupiter? You know, if you are the first person to land on a body it's usually named after you. How about that? Maybe there will be a Jupiter moon called *de Witt*."

"More likely *de half-wit*." Vido fended off her lunge. "Hey! I thought you were on your best behavior."

He ran for the exit pursued by Gladys. Polly soon followed. Rick and Deedee were left sitting alone.

"You look pretty wiped out," she said. "Do you feel too tired to talk?"

The peculiar tone in her voice woke him up at once. "Talk? About what?"

"Not here." Deedee stood up. "If you don't mind, I'd like this to be private. Let's go to my cabin."

Whatever she had in mind, it was surely not what it sounded like. That was just as well. And just as well that she had not suggested his cabin. His bunk still looked as though it had been struck by a tornado. Rick trailed along after Deedee on weary legs, feeling a little uncomfortable as they passed Alice's cabin.

"What's the big mystery?" he said as she closed and locked her door. "Getting paranoid?"

"Maybe I am." She sat down on her bed and gestured to him to use the chair. "I haven't told anyone else about this, because it sounds so crazy. Promise me that what I say to you now won't go any further."

"I promise. I won't talk."

"Not to anyone. Not even to Alice Klein."

"Alice? What makes you think that I might. . . ." Rick saw Deedee's expression, and swallowed the rest of the sentence. "I promise. Not to Alice, not to anyone."

"Thank you. I want to ask you a question about somebody—don't worry, it's not about Alice."

"Go ahead."

"What do you think of Jigger Tait?"

"Jigger?" It was the last name that Rick had expected. He had to stop and analyze his own feelings before he could answer. "You probably know him as well as I do," he said at last. "I think very well of him. He helped me a lot back on CM-2, when I did something really stupid, and he never mentioned it to anyone. He keeps himself

to himself, but he's always there when you need him. What are you getting at, Deedee?"

"I'm not sure. Until two days ago I'd have agreed with everything you just said. We've seen a lot of weird things since we shipped up from Earth, and Jigger has been one of our only points of continuity. It's almost uncanny, the way he shows up when anything is happening—like when you had your fight with Vido—but you always felt you could rely on him."

"So what happened two days ago?" It seemed to Rick that she was having trouble getting to the point. Diffidence and uncertainty were not the usual Deedee. "Spit it out, Dee."

"Remember the big group meeting with Barney, the first one we had after we got here? She started to talk about assignments, and I had left my problem set in my room. I sneaked out while she was going over the list of what came next, and I came back here to pick it up. And I saw Jigger. He didn't see me, but it looked as though he had just come out of my room and was heading away along the corridor."

"Why didn't you say something to him?"

"I was too surprised—and I was in a hurry to get back to the meeting. But it looked like he was going into Goggles Landau's room. After the meeting with Barney was over, I asked Goggles if he had been doing any work with Jigger. He said 'Work? No. I haven't spoken to Jigger since we got here,' and he stared at me as though I was off the wall."

"Why didn't you talk to Barney?"

"And tell her what? I couldn't see any sign in my room that Jigger had been there. I wasn't even sure he had. Barney would have ripped me to pieces."

"She might." Rick tried to sound sympathetic, and failed. "She certainly ought to. You didn't see anything. Nothing happened to your room, or Goggles's. You don't have a thing to go on, except some weird suspicion."

"I haven't finished," Deedee said quietly. "I knew all that, but I was still worried. Today we were all together in the smelter, and it was the first time the whole group had met in two days. I don't know if you noticed, but Gina Styann was there as well as Barney French. Everybody who came out to CM-26 with us was there—except Jigger."

"So? He was busy elsewhere."

"He was. I sneaked out of the SM before the meeting ended, and came back here to my room. I left my door open, but I stayed out of sight on my bunk. If Jigger came along and saw me I was going to say I wasn't feeling good. And he *did* come along."

"Into your room?"

"No. But he went into Alice Klein's, and he went into Skip Chung's. He was about ten minutes in each one."

"Why didn't you go in after him?" It was the obvious thing to do, and Rick was losing patience. "Just ask him what he was doing there."

"This is going to sound stupid, Rick, but I was scared. I *am* scared. It's like you feel you know someone really well, and then they suddenly do something so out of character that you realize you don't know them at

all. Can you understand that?"

Rick thought he understood exactly. It was his own feeling, right now. This wasn't the Deedee Mao that he knew and liked.

"What do you want me to do, Dee?"

"I don't know. I guess for the moment, nothing. I'm going to keep an eye on Jigger, and on anyone else who comes prowling near my room for the next few days." She paused. "But if anything bad should happen to me—well, I want to be sure that at least one person around here will be asking questions."

Rick didn't forget what Deedee had said, but the activities of the next few days pushed it away from the center of his attention.

For one thing, he had grappled hard with the problem of the spinning ring, to the point where he believed that he knew what must happen. After many hours he could see that hoop, rotating in front of his eyes. It was spinning about the center of attraction. Then you cut all the strings. At that point the ring would wobble, just the tiniest bit, because any real system always did. One side of the hoop would move a fraction closer to the center of attraction. Once that happened that same part would be pulled a little bit harder toward the center by the gravitational force, because gravity was stronger with decreasing distance. At the same time, because that side was closer to the center of rotation but the rotation speed hadn't changed, the outward centrifugal force on it would become

a tiny bit less. Both those would act to make that part of the hoop move *toward* the center of attraction.

Meanwhile, because the hoop was strong and solid, the part on the opposite side had to be pushed a little bit farther away from the center of attraction. The gravity force on it would be less, and the centrifugal force bigger. That part of the hoop would feel a force to move it *away* from the center of attraction. In other words, both sides of the hoop would feel forces that amplified the original wobble. The hoop would move more and more off-center, until part of it hit the central attracting point. The strings had been absolutely essential, to prevent any asymmetry in the movement growing and growing.

That was the mental picture. Unfortunately, Rick knew there was no way he could put it into mathematics. The tools were still far beyond him, and his deadline for submission of an answer was close. He wrote out, carefully and laboriously, his train of logic, and added a note: *For the same reason, if the rings of Saturn were solid hoops, their motion would be unstable. They would move until a part of every ring hit the planet and the whole thing would disintegrate.*

He checked the spelling of every doubtful word, worried about what he might have missed, and handed his efforts over to Barney French. She looked at him skeptically when he said he thought he had the answer, but she offered no comment. Even after he had handed in his solution he could not stop thinking about the problem. His obsession ended only

when the time came to leave the main body of the station to work on the clean-up of the SM.

The smelter had been filled with air, and after the apprentices had stripped off their suits each one of them was assigned a section of the inner wall to scrape clean.

"Good enough to see your face in every bit," Barney French announced. "Until it's like that, you're not finished. It's possible, because it's been done before. The last group of apprentices managed the whole thing in two days."

She might have meant to encourage, but after four hours of unpleasant work her words had the opposite effect. Every apprentice was filthy, covered by a layer of metallic ash and gritty powder. It was in their eyes, ears, and hair, and when they paused for a meal break they could feel it grinding between their teeth. Rick, looking at the section assigned to him, realized that he had done no more than 5 percent of the work. At this rate he would be at it for weeks.

When the work first started the apprentices had been cheerful and talkative. During the second four-hour stint they were all looking at their neighbors, wondering if someone else had been given an easier or a smaller section to work on. Not one of them could see any hope of finishing the job in two days.

Finally Barney told them it was time to quit. She was still cheerful—and clean. She had kept her suit on, and ash and grit did not stick to it. Exposed skin was another matter. The grime that went on so easily was the

very devil to get off. Rick, after half an hour of effort, still went to bed with matted hair and the taste of metallic oxides in his mouth.

The next morning he returned to the main hall, reluctantly ready to go back to work. He was a little surprised to see Polly Quint already there and standing next to Barney French. Polly was a notorious sluggard, usually the last to arrive at any event beginning before noon. She was grinning all over her face.

That should have been enough to make Rick suspicious. Polly should be anything but pleased with the labor ahead—labor enough to bring a swarm of civil liberties' lawyers if you forced convicted murderers to do it back on Earth.

Barney waited until everyone was there, then took Polly's hand and raised it above her head.

"The winner—and the only one. You ought to give her three cheers."

And, when that was greeted with baffled silence, "The only one to win what and do what, you ask? The only person to use her brains. Did you enjoy yesterday's work? No, I'll bet you didn't, not unless there's something wrong with you. But it wasn't enough to make you *think*. What's the most important quality in this phase of your training?"

"Initiative." The muttered word came from everyone in the group.

"Exactly. Initiative. I'll let you get away with a lot of other things if you show enough of that. Polly, tell them what you did last night."

Polly gave Barney French an imploring "Do I have to?" look, but was

offered no way out. She shrugged.

"Like everybody else, I spent two hours trying to remove grit from my hair. After that I went to the data banks, and I made an inquiry. We know that the interior of the SM can be heated, because it is able to smelt ore bodies. We also know that it can be filled with air, because we were there all day yesterday. I asked for the maximum temperature that the inside of the SM can be taken to when it's filled with air—or oxygen—without damaging any part of the structure or the instruments. The answer is, over four thousand degrees. That would be enough to oxidize all the junk on the inside walls, and turn it to gas. Then if you opened up the end of the SM, which we know you can, all the crud-dy gas would blow out into space. You'd have a perfectly clean interior. And one person could do the whole job—without even breaking a nail. That's when I went and asked Barney French if what I was thinking of was forbidden, for some reason I did not understand. And it isn't."

It had been dawning on the rest of them, sentence by sentence, that they had been granted a reprieve. Weeks of horrible grimy labor was about to vanish, puffed into space in a cloud of metallic and silicon oxides. What Polly received was not exactly three cheers, but it was lots of whistles, waving arms, and "Yay, Polly."

"Thanks, you beauty," Chick Teazle shouted, loud enough for everyone to hear. "I'll love you forever."

"That's not what I've heard," she called back. "They say you can't last thirty seconds."

His reply was lost in jeers and cat-calls.

"All right." Barney clapped her hands. "Anybody have a question for Polly?"

"How did you come up with the idea so quick?" called Goggles Landau.

"You ought to ask, what took me so long?" Polly grimaced in self-disgust. "As soon as I could walk and talk, my stepmother had me helping her in the shelter kitchen. I've known how to use a self-cleaning oven since I was six. It didn't take much brains to apply the same idea to the smelter."

"But you were the only one who did it," Barney said. "Take credit from me when you can get it—I'm not that way inclined. For the rest of you, since there's no more scraping to be done you are all dismissed for the rest of the morning. Polly will direct the superheated clean-out of the smelter later today, and you will all help. Meet at the main lock at two, in your suits. Until then your time is your own."

The apprentices dispersed in a good humor. Thanks to Polly they were off the hook from days or weeks of pointless labor. In Rick's case the satisfaction lasted only a few minutes. The true situation hit him when he reached his cabin, and found waiting there his solution of the spinning hoop problem along with Barney French's comments.

This is really rather good, she had written on his answer—extravagant praise by Barney's standards. No one else in the group has managed a solution, and from what I have seen so far I suspect that no one else will.

You are still hindered by your lack of mathematics, but that will come with perseverance. You are not a born mathematician, like Henrik Voelker, but I'm rather glad you're not—if you were you'd have been grabbed by the central office—

Henrik? The Carolina Kid. The central office? It occurred to Rick for the first time that there might be other paths to success in Vanguard Mining. Henrik had flunked the training course, back on CM-2. Rick had felt sorry for him, because he was an OK type but such a goofball. Apparently he was still with the company, performing a different job. The East Coasters who said that Henrik was a mad genius must have been right after all.

—But there are more important things than mathematical talent if you want to be a good mining engineer. Remember, the purpose of mathematical calculation in the physical sciences is not numbers, it is insight. Your discussion of this question displays both insight and ingenuity.

If Rick had received that note earlier in the day, he would have been ecstatic. Now, though, he had to compare what he had done with Polly's achievement.

It was no contest. His problem had been explicitly stated and identified. Its solution had to be in a hundred data banks and a thousand textbooks. But Polly had taken a real-world situation, identified it as a problem without being told it *was* a problem, and produced a real-world solution.

No wonder that she had received

applause and praise.

And if achievement counted for anything, she was now far ahead of the rest—including Rick—as a candidate for the fabulous expedition to the Jovian moons.

CHAPTER SEVENTEEN

You may feel SICK, you may feel SAD, you may feel STUPID, you may feel SUPERIOR, you may even feel SEXY...

The sign hung prominently displayed at the entrance to the airlock.

... But unless you are feeling SUICIDAL you will check every element of your suit before you operate this lock. YOU HAVE BEEN WARNED.

Rick was feeling somber, which was not on the list, but he did not ignore the sign. He carefully made sure of every seal and function of his suit. He had not felt much like eating, and less like talking, and while all the others were still at lunch he had left to come straight here. It would be another hour before the operation at the SM was due to begin, but he wanted to spend time alone. The best place for quiet solo thinking, better even than his cabin, was outside the busy main body of CM-26. Inside the asteroid there was always the subterranean grumble and growl of heavy machinery, a reminder that apart from being a training facility CM-26 was also a producing mine.

It was a surprise and a nuisance to Rick to make his exit from the airlock and see the faint beacon of another suited figure flashing red near the smelter. While he watched it disappeared around the curve of the cylin-

der, then a couple of minutes later came into view again on the other side.

Who on earth was it? All the apprentices had been in the dining room. He saw no way that they could have arrived here ahead of him.

There was an easy way to find out: use his suit radio. But then he would be forced into unwanted conversation. Maybe the other would simply go farther away, off toward the cluster of small waiting asteroids beyond the SM, or perhaps around to the other side of CM-26 where the final products of the mine were launched on their trajectories toward distant Earth.

Rick dimmed his own beacon, hovered in space, and watched. The other person's suit was invisible whenever it was in shadow, but the beacon allowed Rick to track every movement. It went round and round the smelter, starting at the bottom and steadily spiraling up to the top. When that was done the flashing red light made a double traverse of each end of the cylinder, and finally the suited figure turned to jet back toward Rick and the main airlock.

He could not avoid contact now. But at least the question of identity would be answered. Rick waited, and knew the exact moment when the other saw him. There was a reflexive jerk in the suit's arms and head, followed by a slight alteration of thrust vector.

"You're pretty early," said a voice in Rick's headset.

It was Jigger Tait, heading straight toward him.

"Yeah. You too." Rick at once

thought of Deedee's worried face. There was no reason at all why Jigger should *not* be out here—he was senior enough to go anywhere he pleased—but that did not explain why he would *choose* to be wandering around outside, alone.

"You mean for heat-cleaning the smelter?" Jigger spoke casually, as though meeting Rick was the most natural thing possible. "Oh, I won't be staying for that. I've seen it before, with other apprentice groups, and anyway I have work that needs doing inside. I'll see you later."

He jetted off and entered the open outer door of the airlock, leaving Rick perplexed. Jigger had offered not one word of explanation as to what he was doing. Rick could think of no reason why Jigger needed to be wandering around—*prowling* around, in Deedee's word—the smelting module. On the other hand, if Jigger wanted to prowl the *interior* unobserved, he would soon have the perfect opportunity with the apprentices all busy outside.

Hopes for a quiet half-hour of serious thinking had faded at the first sight of that red spacesuit beacon. It faded farther when the airlock opened again and another suited figure emerged.

Rick's initial thought—Jigger returning—vanished with one look at the newcomer. She was as slim as Jigger was muscular, and considerably shorter. He also knew exactly who it was. An apprentice's style in manipulating the motion controls of a spacesuit was as individual as a walk.

"Hi, Alice." Rick moved toward her.

"We're early."

She must have expected to be alone, because he saw the instinctive jerk of surprise.

"Rick? I didn't think there would be anybody else out here yet."

"Me neither." He advanced until they were within a few feet of each other. "But you were exactly right. Initiative is the name of the game, and Polly sure grabbed it."

"For today she did." Alice didn't sound upset, the way that Rick felt. "What was it you told me Vido Valdez said, when the two of you were always fighting? Are you still fighting, by the way?"

"No. We get on just fine."

"But you're not close?"

"No, I wouldn't say we are." The conversation wasn't making a lot of sense to Rick. "What Vido said to me when?"

"When Dr. Bretherton told the two of you to cool it, or get thrown out."

"Oh, yeah. Vido told me, 'It ain't over 'til I say it's over.'"

"That's what I meant. Well, I feel the same about Polly. She's riding high at the moment, but she hasn't won until we say she has. We just have to come up with better ideas."

"Great." Rick knew his skepticism was showing through. "Got any?"

"Not yet. That's why I'm here. But we will have. Come on."

She led the way over to the smelter. It was open and airless and they wandered inside it together, examining the odd airlock, the places where suits could be stored, and the array of monitoring instruments on the lower flat end. They looked at the great in-

ductive heating coils, which would soon raise the whole interior to a temperature of thousands of degrees. At the other end of the smelter Alice made another inspection of the control panel that allowed the segmented metal sectors to iris open or to close for an airtight seal. Finally they moved together along the curved outer surface of the cylinder, studying the little fusion drives that caused the cylinder to spin on its central axis or to slow to a halt.

"Ideas?" Rick asked as they cycled back to their starting point at the base of the cylinder.

"Some. I don't want to talk about them, though—they're still half-baked."

Rick understood that completely. You might get what seemed like the world's greatest idea for the first half hour, and a day later you'd realize that it was a complete crock. In any case, this was no time for discussing secrets. The rest of the apprentices were beginning to appear from the lock, wandering in small groups over to the smelter. Because Rick and Alice were already there, it was natural for the others to treat them as a group center and gather around them.

Polly arrived last, followed by Barney French. "I would like to describe the plan for today," she said in a wobbly voice, while she was still approaching the rest of the group.

She was nervous, and no wonder. Everyone would have a role, but this was Polly's show. Barney wouldn't let her do anything that might destroy or damage the smelter, but it would be almost as bad to be given a public

warning, or to have one of the other apprentices point out why what she was suggesting was crazy and dangerous.

Polly moved to stand in front of the triple airlock. "The good news," she said, "is that we won't have to worry about rotating the smelter, because we don't have ore to melt and centrifuge. That means we don't need to inspect the fusion engines on the outside. The other good news is that we won't need to go to four thousand degrees, even though the structure can stand it. Twenty-eight hundred degrees will be enough to oxidize and vaporize all the residues that line the smelter.

"Finally, we won't need anything like full atmospheric pressure for this to work. If we use pure oxygen at one-thirtieth of a standard atmosphere, that will do nicely.

"The bad news is something that I didn't realize when I first thought of using heat to clean the inside of the smelter. When you melt a metallic asteroid by electric inductive heating, there is good conduction through all parts of it. In other words, heat travels easily to everything you want to melt. But we are dealing with just a thin layer of residue, too thin in places to conduct much of anything—heat or electricity. That means induction is inefficient, and so is conduction. Instead, we have to make the whole interior of the smelter into a radiating enclosure at a uniform temperature—a black body, that's called in physics. Unfortunately I don't know anything about black bodies—regardless of what some people around here might think."

It produced a laugh, as Polly had intended. Rumors of her affair with Vido Valdez, darkest-skinned of all the apprentices, were widespread.

"I still don't understand black body radiation," she went on. "Chick Teazle did all the work for me, and I want to give him credit."

"Credit for me if it works," Chick said cheerfully. "But Polly's fault if it goes wrong."

"It had better not go wrong." Now Polly was not joking. She had too much riding on this. "I've worked up the inspection schedule that has to be done before we begin, and the assignment for each of you will show on your suit's interior display. If anybody doesn't know what to do, or has trouble when they start doing it, come back to me. I'll be standing right here."

Rick's assignment was straightforward: inspect the power supply for four of the inductive heating units on the periphery of the smelter. As he moved to do it, he realized that Polly had the worst job of all. She would just hover in space with no assignment, waiting and worrying until everyone else was finished.

On the other hand, he wasn't going to skimp his own task for the sake of Polly's peace of mind. He checked the power supply, slowly and systematically, then the transformers, and finally the inductive coils themselves. Beside him, Gladys de Witt did the same thing for four other units. In the well-lit interior he could recognize her by the color coding bars on her suit.

"Sure beats scraping," she said, as they finished the job and moved to-

gether back to the exterior of the smelter. "Wish I'd thought of it."

Polly and Barney French were waiting for them with half a dozen of the apprentices. Others came drifting back, in ones and twos, while Polly kept an audible head count. Last of all were Vido Valdez and Alice Klein, appearing together around the outside of the smelter.

"Right," Polly said. She sounded breathless, although she had not moved for the past half hour. "All in working order. Time to pressurize. I'll give the command, but you'll all be receiving the same displays as I will."

Status monitors flashed their reports onto Rick's suit display. There was nothing to see at the smelter itself, where both ends were now closed and airtight. The internal gas pressure crept slowly up to one thirtieth of an atmosphere.

"Now we're going to begin heating," said Polly. "Before we start, we'll all get well out of the way."

She led them away from the smelter and away from the main body of CM-26, to where the cluster of small co-orbiting asteroids waited.

"I don't see how anything can go wrong," she said, "but just in case, we will use one of these as shielding masses. Get close to it, so you can see the SM but if you need to you can duck out of the way."

As the apprentices moved into position, Rick noticed that Barney French was doing her own head count and assessment of position. She moved one person—Rick thought it was Lafe Eklund—back a little, so that he was better shielded by the asteroid's bulk.

Finally she nodded to Polly.

"Here goes." Polly's words sounded more like a prayer than a statement. Again there was nothing to see at the SM, but the suit displays showed a massive drain on the central power supply, and almost at once a rapid rise in ambient interior temperature.

Five hundred degrees—eight hundred—eleven hundred.

Rick, like everyone else, stared in fascination at the smelter. He realized that it was another of the million facts he did not know about this sort of mining. How high a temperature did a body have to reach before it turned red-hot? How high before it was orange or white-hot? *Twelve hundred degrees*, read the display. Shouldn't the heated SM be glowing now against its background of stars?

"We don't like to waste power," Barney French said suddenly, as though she was reading Rick's mind, "so there is excellent thermal insulation between the SM's interior and exterior. You won't see a thing from here. But if you were inside—and managed to survive—you would find the walls starting to glow red at five hundred Celsius. If you were inside now, at twelve hundred degrees, they would be white-hot.

"We still have a way to go. To give you an idea of what we're dealing with here, iron and nickel both melt at about fifteen hundred and boil at twenty-seven hundred. Silicon boils at twenty-three hundred, silicon oxide at twenty-two hundred. We don't have any platinum or iridium in the dross, which is just as well, because platinum doesn't boil until thirty-eight

hundred and iridium at over forty-one hundred. Mining can be warm work."

The temperature had been climbing fast. It was up to eighteen hundred degrees. Rick tried to imagine the inferno inside the smelter. The oxygen would have gobbled up any pure metal into compounds, and the dross would be beginning to vaporize. The internal pressure had gone up, to more than a fifth of an atmosphere, and it was still rising.

The inside pressure and temperature were now increasing in unison. There must be a simple explanation for that, if only he could think of it.

"Twenty-two hundred," Polly said nervously, although every apprentice could see that on the suit display. "Three more minutes, and we'll hit twenty-seven. I'm going to cut power then and hold it for another two minutes, then give the command to open the big end as wide as it will go."

"And what will happen then?" Barney asked the question in—for her—an oddly gentle voice.

"The gas inside will blow out. The inside will be left clean."

"True. But something else will happen that we have to worry about. I wanted you to have the first chance with this, Polly, but now I'm going to open it up. Anybody. What do we have to do when we let the gas inside blow into space?"

There was a long silence. "Stay out of the way?" Chick Teazle said, in a let's-try-anything voice.

"That, certainly. What else?"

It was a real-time contest, the worst one yet. Rick struggled to visualize the operation. The gas inside was su-

perheated, but there was no way it could damage anything when it came out through the opening aperture at the end of the smelter. It came out hard, because the inside pressure had increased to a third of an atmosphere. *Jettied out.*

"Rocket!" he shouted, afraid that someone else would beat him to it.

"Be more specific, Rick."

"The gas that comes out will be in a jet, it will produce a rocket effect just like the drive on a ship. The smelter will be driven in the other direction."

"So what do we need to do?"

"Balance it." That came as a shriek from Polly, not Rick. "Use the little thrusters on the outside of the smelter to equal the push from the escaping gas. But I don't know how to work out the thrust!"

"Nor does anyone else in the group," Barney said. "But I do! You're feeling crushed, Polly, but you shouldn't. This exercise makes two points. First, you all have a way to go before you look like mining engineers. Second—and more important—what you do when you work for Vanguard will almost never be a solo effort. You are part of a team, and no matter how much you want to succeed you should never forget that. Here's the information for the impulse correction."

Thruster settings flashed onto the suit displays. Obviously, Barney had computed and stored them in advance. The necessary counter-thrust was small. Rick realized that nothing catastrophic would have happened, even if Polly had proceeded as she originally planned. The smelter would have moved away from CM-26 at a

modest pace, and a ship would have been forced to go out and bring it back. Barney had interfered to make a point, not to prevent an accident.

"Let's do it," said Barney. "Go ahead, Polly."

At last, there was something to see. The end of the smelter began to open, and a cloud of incandescent gas spewed out into space. At the same moment half a dozen thrust units on the side of the SM flared briefly into action. To Rick's eyes, calibrating the position of the smelter against the starry background, nothing moved so much as a millimeter. From where he was hanging in space he could see into the open maw of the smelter. The inside shone a brilliant white, which as he watched faded to orange, to bright cherry-red, and at last to the dull glow of a dying ember.

"Don't even think of it," Barney said. A few of the suited apprentices were already floating in the direction of the smelter. "You won't be able to go inside and see what it's like without frying for another couple of hours. Let's go and have a meal and come back later. You should be feeling good about things. I told you that the last group of apprentices finished the cleaning job in two days—but I didn't tell you that they needed until nearly midnight.

"You beat them by"—she consulted her suit chronometer—"more than six hours. You've earned a reward. You can tell me later what it will be. Polly gets a veto vote, because you couldn't have done this without her brain-wave."

A reward. All through the meal the

preferences had been kicked around. A party, a dance, a feast, a day without work assignments.

The knock-'em-dead idea did not emerge until they were back in their suits, examining the results of the fiery purge of the SM.

Those results were spectacular. The smelter wasn't just *clean*, it was immaculate. Not a trace of grime or metal residue or dust of any kind could be seen anywhere. The instruments and walls shone like new.

"So what do you think?" Polly sounded diffident, but Rick could see her eyes, bright behind her visor.

"Super-colossal-amazing." Deedee was standing next to her, and she reached down and ran her glove over one of the plane surfaces. It came away spotless. "Clean enough to eat off."

She paused, and she and Polly stood staring at each other.

"That's it!" Polly exclaimed.

"If we're allowed to," said Deedee.

"Allowed to what?" Obviously, Polly and Deedee had communicated an idea. Just as obviously, Rick had been present but somehow left out.

"Party, of course," said Polly, in tones that suggested any fool would know.

"In *here*," Deedee added. "We said it's clean enough to eat off the floor—so let's do it."

"Eat, and dance, and riot."

"If Barney will let us."

"Why shouldn't she? We'd have to fill it with air, of course, so we won't need suits."

"And we'd have to bring food and drink over—no way we could pre-

pare it here."

"And a little cylinder rotation, to give enough gravity to dance."

"And we'd want partitions, for privacy."

"And couches in them, for you-know-what."

They were off and running, while he was totally ignored. After another couple of exchanges he gave up and moved away. It was obvious that they didn't need him.

Not for the first time, Rick decided that males and females spoke different languages. It was a mystery that they were even considered the same species.

CHAPTER EIGHTEEN

Chick Teazle had been put in charge of arrangements; not, as Barney French explained to him, because he was especially competent, but because he was so obnoxious that people would do what he asked rather than get into an argument with him.

He was also, though Barney did not mention it, a natural organizer who loved jobs like this. For the past twenty-four hours he had hardly slept, planning out the work needed to make a Cinderella transition from ore smelter to dance hall.

"We spin it *first*, and get some decent internal gravity," he said to the apprentices, assembled in the main training hall of CM-26. "We need gravity for good dancing, and for sitting comfortable. And we fill the SM with air *last*. That way we can bring in partitions and food and drink and everything else through the big open end, and not have to keep using the airlock."

"Suits all the time?" asked Deedee. Even after months of experience, no one really liked working in suits.

"Well, not for the party itself. Just for setting it up. Once that's done and the SM is airtight, we take off our suits." Chick produced a gigantic sheet of hardboard, covered with minute writing. "Here's the schedule for everything, with names attached to individual tasks. We'll eat tonight over in the SM, but that means we have to be finished with everything here before dinner time."

Gladys de Witt was studying the board. "I see my name, and most people's; but I don't see Vido and Alice and Deedee and Rick."

"They go anywhere we have to go, do whatever needs to be done. They're the trouble-shooters, along with me."

"What trouble?"

Chick sighed. "If I knew that, it wouldn't be trouble, would it? It would be shown on the board. Trouble is what you don't expect. We've never done anything like this before, I bet we'll run into a hundred things that don't work out quite the way I planned it. Look, do you want a debate, or do you want a party?"

"Party!" Anything that Gladys might have said was drowned out by the shout from everyone else.

"So let's get going." Chick held out the hardboard sheet. "If anybody has questions at this end, Vido and Alice will be here to answer them. Deedee and Rick will handle problems over in the SM. I'll be floating all over."

Any notion that the trouble-shooters might have it easier than anyone

else was dispelled in the first half-hour. Spinning the smelter on its central axis, to give a comfortable and familiar quarter-g field at the outer surface, was easy and went exactly as planned. But when the work team went inside they were out again within seconds.

Lafe Eklund came floating over to where Rick and Deedee were waiting. "We're all right for the moment," he said, "because we're getting sunlight in through the open end. But when we close that, the partitions we want will make it too dark for the party. We're going to need more internal lights."

Deedee looked at Rick. She seemed to have something on her mind, and he thought that she had been tentatively working her way around to discussing it. But now she said abruptly, "The lights will have to come from the main base. I'll go get some."

She jetted away, leaving Rick to wonder what was going on. Alice had been with him in his room the previous night. Did Deedee know that? Alice's room was next to hers. Even if she did, why did she care? He thought of the last party, back on CM-2, when he had danced all evening with Deedee. Was she expecting or hoping that he would do the same again? *Would* he do the same again? Did he want to?

Rick was having trouble sorting out his own feelings, but he had no time to brood on personal matters. Lafe Eklund had been gone less than two minutes, and already he was coming back.

"We could really use another pair of

hands," he said. "We can bring partitions in easily through the open end, and we can move them to the curved floor. But because the SM is spinning pretty fast, the floor is moving relative to the partitions when they get there. One person can't handle them."

"How many partitions?"

"Altogether? About forty. And we have eight tables, and forty chairs, and the sound system, and all the food dispensers."

"Then I've got a better answer." Rick felt useful for the first time. "I can slow the spin way down, until all the inside fixtures are on the floor and secured, then spin back up again. Gravity's great for dancing, but it's a pain during installation. Give me five minutes."

As he moved around the outside of the smelter, Rick sent a radio message back to tell Chick Teazle what he was doing. Chick's instinct had been quite right. Plan all you liked, and there would still be a hundred things that had to be done a little differently.

It was easy to see why Lafe had complained. A quarter-g field on the circumference of the SM might be fine for eating or dancing, but to achieve that the whole cylinder was spinning around on its axis once every eighteen seconds. That didn't sound fast—until you realized that partitions you brought in from outside had to be seated on a curved surface moving past them at seven meters a second. That was as fast as most people could run.

Rick used the drives to slow the spin to a more stately rotation, once every minute. The effective field at

the outer curved surface would go down to—what? He struggled to calculate an answer in his head, and failed.

Well, it would go down a lot, from a quarter-*g* to maybe a fortieth of a *g*. Installation work would be much easier.

But it might not be trivial. Rick headed around to the open end of the smelter and moved inside, to see how things were going. Lafe Eklund gave him a thumbs-up sign. The partitions were floating down easily into position and being secured by a superglue that held at anything from absolute zero to a thousand degrees.

It was tempting to join Lafe and his group at their work. Rick told himself that was not his job. He was supposed to save himself for things that weren't going well. But when Deedee returned with a dozen light fixtures, he helped her to pick good positions and install them. This was a task that had not been anticipated, so it was a natural for the troubleshooters.

He was half expecting Deedee to pick up their earlier conversation, but apparently in her absence she had changed her mind. Her comments were all technical. It was Rick, to his surprise, who found himself gesturing to her to turn off her radio. He placed his helmet next to hers. "Got any plans for the party?"

She stared at him, but even with the bright new lights he could not see her eyes inside her suit's visor. "What do you mean, plans? Maybe I do. Why?"

"I thought you might be willing to give me dance lessons again. I mean, if you still like to dance with fire hy-

drants. I'm the nearest thing to it within three hundred million kilometers."

"Is that your idea of a graceful invitation?" But she didn't sound angry, only amused and thoughtful. "I sort of told Chick Teazle that he and I might make a couple."

"Oh." Rick bit back a question about Chick and Deedee. "Pity."

"It wasn't definite, though. I can tell him I changed my mind." Deedee turned, so that at last he could see her face. She was frowning. "But what about you—and Alice? I mean, I thought that you two—"

"It's nothing definite." Rick knew that was a whopping lie, and he could be getting into big trouble. It was true that he and Alice had never gone public, but in private they had done things that Rick never dreamed of before. Maybe Alice would want him to dance with her tonight. Maybe she would finally forget her worries about what the instructors might think of affairs between apprentices—certainly, no one else seemed to care.

"I'd like you to go to the party with me." Rick spoke to end his own uncertainties. "And I'd like you to dance with me."

"Just you?"

Rick swallowed, and took the plunge. "Just me. Nobody else."

"Then I will." Deedee gave Rick a glowing smile, and squeezed his arm in a gloved hand. "Damn these suits. I can't even touch you."

"We won't have to wear suits at the dance. Assuming there is a dance, which there won't be unless we get everything ready." Rick moved his

helmet away from Deedee's and gestured to her to turn her radio on. "We'd better get back to work. There could be a million problems going on right now, and we'd never know it."

"No. If there were, Chick would be buzzing all over the place. But I'd better go talk to him and tell him about tonight."

"Do you think he'll be upset?"

"Suppose he is. Do you want to call it off?"

"No way!"

"Then don't ask stupid questions. I'll be back as soon as I can."

Deedee jetted up to the open top of the smelter and vanished around the outside. Rick realized that he ought to have his own conversation with Alice—and soon. He was probably a jerk, but if Deedee wanted to do more than dance tonight he knew he would not hesitate.

Alice was over at the main station, handling problems there with Vido. And Rick, with Deedee gone off to talk to Chick Teazole, was the only assigned troubleshooter at the smelter. He had to stay until she got back.

Before he could fret over that, other matters took over. Lafe Eklund called to say that the interior work was all done, and Rick could spin the SM back up to a quarter-g field. While he was doing it, what seemed like an army of suited apprentices appeared from the main body of CM-26 and came streaming over toward the smelter.

"What's wrong?" he called on his suit radio.

"Wrong?" That was Vido. "Nothing's wrong. That's why we're here."

"We're all done back there." That was Chick, jetting along beside Deedee—if he was heartbroken he certainly didn't sound it. "We have all the food and everything else with us. As soon as you are finished we can fill the inside with air, get out of these suits, and start the party."

"We're done, too," said Lafe. He was standing on the inner surface up near the top of the smelter, checking the apparent gravity as the cylinder gradually leveled off its rate of spin. "Come in through this end. Once you're all inside I'll close it so we can pressurize."

Deedee was moving past Rick, giving him a jaunty wave and a nod that said that she had talked to Chick, and everything was all right.

But it wasn't. Rick hadn't spoken to Alice. He hovered outside as person after person passed him, moving down into the bright and transformed interior of the smelter. Tables and chairs now ran top to bottom along one quadrant of the curved interior, with the food service area taking up another quarter. Half of the other side of the cylinder was a generous dance area. The remainder was cubicles with their own couches, walls, doors—and ceilings. No one would be able to look up from the dining area across the middle of the cylinder, and see what was going on in one of the private rooms on the other side.

Where was Alice? He felt sure that he hadn't missed her.

"Are you coming in?" That was Lafe, waiting at the big open end of the smelter. "We're set to close and fill."

"I'll be another few minutes. Go

ahead and don't worry about me. I can use the airlock at the other end."

It occurred to Rick as he spoke that Alice might be doing exactly that. Maybe instead of moving with the main group into this end of the SM, she was entering through the triple airlock at the other end.

The metal sectors close to him began their ponderous pincer movement, narrowing to seal the circular aperture of the smelter. While they were still closing Rick headed along the outer edge of the cylinder, reflecting that it would be just his luck if Alice happened to be going the other way, out of sight on the far side.

Well, if that were the case she was too late. She would have to return and use the lock, just like him.

He came to the triple airlock and moved into the first of its three compartments. This one could be held at vacuum, or pressurized to the same level as the interior, or partially pressurized at any level in between. The chamber beyond had the same feature, plus enough rack space for dozens of suits. At the moment both locks were hard vacuum, but the pressure gauges showed that the inside of the SM was already filling with air.

Rick remained in the second of the locks and peered through the thick glass port. He saw Barney, he saw Gina, he saw Vido and Lafe and Gladys. He surveyed the whole group, climbing out of their suits. Everyone except Alice was there.

So where was she?

He turned, and was just in time to see a suited figure glide across the edge of his field of view and disappear

from sight around the side of the smelter. Whoever it was had come from the direction of the main body of CM-26—and it was surely not Alice. The suit was far too big and bulky.

It was Jigger Tait. Rick was almost sure, even from that brief glimpse. There was no reason why Jigger should not come to the party; but if that was his intention, why hadn't he headed straight for this airlock?

Rick thought again of Deedee's suspicions that Jigger, with his secret prowling around the mining asteroid, was up to something sinister. The party was a perfect time for anyone to snoop through the apprentices' rooms. But it made little sense to explore out here. And why stay *outside* the SM if you did?

Rick went back through the locks and floated cautiously in the direction that Jigger Tait had taken. He paused as he rounded the end of the smelter. There was no sign of a suit anywhere along the smooth curved side of the cylinder. Open space in all directions seemed just as empty.

Where could Jigger have gone? The only hiding place left was the end of the cylinder, its flat circle still invisible to Rick. He used his suit jets at their lowest setting and crept forward to where he could peer over the curved cylinder edge.

What he saw was totally bewildering. There was not one suited figure, but two—and they were fighting. They were grappling with each other, turning and rolling and kicking in a jumble of arms and legs.

Jigger Tait—and Alice. From this distance there was no doubt at all.

As Rick watched, Jigger used his superior strength and mass to spin Alice around and lock a forearm viciously across her suit's flexible neck piece. He levered hard, cutting off her breathing and resisting her desperate efforts to break free. She kicked and beat at him, but it did no more than turn them end over end in space.

Rick watched, open-mouthed. He was oblivious to his own movement, and he was slowly drifting higher over the cylinder's end plate when the interlocked bodies turned far enough for Alice to catch sight of him.

"Rick!" Her cry was faint and agonized, from lungs starved for air. "Rick. Help me!"

Jigger was killing her. Rick responded instinctively. He jetted right at Tait, hoping to separate the two of them by the sheer force of his collision. It didn't work as planned, because Jigger turned somehow and dipped his shoulder. Rick drove feet-first into that shoulder and the side of Jigger's helmet, partly breaking his hold on Alice and sending them toward the rigid side of the smelter.

Jigger seemed stunned. As his grip loosened, Alice gave a cry of triumph. She turned, wrapped her long legs around Jigger's middle, and fired her suit's jets at maximum impulse. Jigger was driven backwards, headfirst toward the solid wall. It seemed inevitable that the helmet and face plate of his suit would shatter as he hit, but at the last moment his own jets fired laterally. He and Alice spun giddily about their common center of mass. It was her helmet that smashed at high speed into the unyielding cylinder.

Not even hardened plastics could withstand such an impact. Her face plate burst open at eye level. Rick heard a whistling scream on his suit radio as air exploded from Alice's lungs. Her body bounced one way, while Jigger Tait's suit with jets still flaring went spinning off crazily in another direction.

"Rick!" The cry came this time from Tait, flying farther off and struggling to get his suit's movements under control. "Rick—the panel. Hit the Abort key."

Rick, ready to plunge after Alice, paused. If he reached her he did not know what he could for her. But what was Jigger Tait shouting about, with such desperation in his voice?

Rick turned.

The panel. There it was, the control panel, its white cover open. It was right next to him. What did Jigger mean, hit the Abort?

Rick stooped over to look more closely. The control that would open the end of the smelter had been switched to the ON position. The safety override was in operation. The timer was set and counting down even as he watched—eight seconds to go—seven.

His thoughts ran faster than his gloved hand as it slammed for the Abort key.

Seven seconds—the plates at the end of the smelter would be preparing to open.

Six—the apprentices inside were out of their suits and would take minutes to get back into them.

Five—the countdown had not stopped; they would be blown out

with the rush of escaping air.

Four—his friends would all die in the naked vacuum of space.

Rick stared, close to hysteria, as the changing digits kept counting down. At last they froze. Three seconds. The *override* light went out. And then Jigger Tait was standing next to him, his breathing—or was it Rick's own?—harsh and rattling over the suit radio.

"Close," he said. "Too damn close. You almost killed all of us, coming when you did."

"Alice. . . ."

"She's gone. Come on. We have to collect her body."

He jetted off toward a stiff-limbed suit that turned in the Sun's harsh light. Its red beacon light was still forlornly blinking. Rick trailed after him.

"What do we do now?" he said, as they reached Alice.

"Now?" Jigger gathered the body in his arms, staring down into the silent but agonized rictus of death by sudden vacuum. "That's one hell of a question. Now, I guess that you and I go and ruin a party before it's had a chance to get started."

The apprentices were chatting to each other as they wandered through the inside of the smelter, examining and admiring all the new fixtures. The noise level had been growing steadily.

Then Jigger appeared from the inner airlock. Alice's dead body, still in its suit, was cradled to his chest. Many people had been looking the other way, but somehow the whole giant enclosure at once became uncannily silent.

"Alice?" said an uncertain voice. It

was Vido Valdez, standing like a statue near the lock. "Is that Alice?"

"Not really." Jigger, with Rick right behind him, moved to the area equipped for serving food and laid the body gently onto one of the tables.

"But it is," said Rick, wondering if Jigger had lost his mind. It was understandable if he had. Rick himself did not feel like a human being, he was numb and dead inside. "It's Alice—Alice Klein."

"No. You thought she was Alice Klein, but this woman is Moira Lindstrom." Jigger lifted his head and stared around at the closing circle of apprentices. He inhaled and exhaled deeply, like a man who has been holding his breath for a long time. "I received a confirming call less than an hour ago from headquarters. She is twenty-six years old. And she works—worked—for Avant Mining, not Vanguard Mining."

Gina Styran and Barney French stepped forward to stand by Alice's body.

"She's the one?" said Gina.

"No doubt about it. We caught her in the act. She had overridden the safety and she was all set to open the smelter. If Luban and I hadn't come along when we did, she'd have killed the lot of you. The whole group of apprentices, plus Gina and Barney."

The expression on Jigger's face ordered Rick, about to blurt out that he had been no help, to keep quiet.

Gina was nodding slowly. "So that was it. I wondered." She turned to face the shocked group. "It's time to explain a few things that we couldn't tell you about before. For over a year

we've known of efforts to ruin Vanguard Mining operations. We were pretty sure that it was Avant Mining's work, but we had no proof. The 'accident' that you saw on CM-31 was a good example. It was deliberate sabotage, a planted explosive on the outer surface of the smelting cylinder. Jigger and I suspected as much when Morse Watanabe and the Avant Mining ship, the *Scarab*, just 'happened' to come along at precisely the right time to claim a derelict. He had no way of knowing that two survivors had avoided the blow-up by being outside the habitat, or that we would arrive on the scene so quickly.

"We had suspicions, but that was all. And we had no proof that a saboteur had been planted in the latest group of trainees. So far as we were concerned, every one of you was suspect. But we were able to narrow it down, bit by bit. When Alice Klein told Barney that she didn't feel well, earlier today, we didn't like the sound of that. It meant that she, and she alone, might not be here at the smelter tonight. Jigger agreed to hang behind and keep an eye on her."

"I nearly failed." Jigger again stared straight at Rick. "She was a smart operator, smart enough to fool any of us most of the time. She sneaked out of a cargo lock instead of the usual exit, and she was on the way here before I knew it. Good thing I was already in my suit, just in case. But you're all lucky to be alive."

"We *are* alive. That's what matters." Barney French had been watching the apprentices closely, monitoring their expressions. "Look, it's quite obvious

that this is no time for any sort of party. We are going back to the main station. On the way you can think about this whole thing, and when we get there we'll meet in the main hall. If you have questions, I'll try to answer them."

"But what—" Chick Teazole started.

"I said *there*, not here." Barney clapped her hands. "Come on, do it." She turned to Rick and added in a lower voice. "You join us later if you want to. For the moment, you go with Jigger. No questions—just go."

No questions.

Rick drearily followed Jigger Tait, away from the smelter and into Jigger's private room in the main body of CM-26.

No questions—when he had a thousand, starting to percolate up from the depths of his numbed brain. But more disturbing than any question was a growing conviction. If Alice was a saboteur, planted in the group way back at the time of the first tests on Earth, then her whole relationship with Rick had been a lie. They had been intimate physically, but she could not have felt real affection for him. He was just a dupe.

"I'm afraid you're right." Jigger Tait was draped over a chair, his forearms along its back and his chin on his fists. "She picked you out, but I doubt that she had any special fondness for you. She was working on Vido Valdez, too, just in case."

"She thought I was an idiot," Rick said bitterly.

"Not an idiot, or you would have been no use to her. She probably

thought you were bright, but she knew you were sexually inexperienced. She had that innocent little-girl look, when in fact she was anything but. I'm sure she planned to use sex as part of her control technique, something that would help her to manipulate you when the time came." When Rick grunted but did not speak, Jigger went on, "Don't feel too bad about that. It has worked right through history, on everyone from emperors to peasants."

"What was she going to make me do?"

"I don't know. My bet is that it would have been something deadly to you. You're very lucky to be alive. She saw an opportunity tonight to wipe out the entire group of apprentices in one go, so she grabbed the chance without calling on you. If she had succeeded, I think she'd have tried to make the whole thing look like an accident, the way that the destruction of CM-31 was supposed to be an accident. If the *Scarab* had arrived before us you can bet that all evidence of sabotage would have disappeared before anyone else could see it."

Rick recalled Jigger's face, glaring at the vanishing plume of the *Scarab*'s exhaust. "You knew all that, didn't you, when the *Scarab* first appeared? That's why you were so angry and rude. But how did you know? I mean, what made you suspicious when the rest of us didn't have a clue?"

"I was afraid you'd ask me that." Jigger's big moon face was gloomy, and he shook his head. "I could make up a story, but one of you would see through it. Didn't it strike you as

strange that Gina and I have been with you all the time, right from your flight from Earth up to CM-2?"

"I never thought it was anything out of the ordinary. Deedee did, though. She said you'd been snooping. She pointed it out to me, and said we ought to keep an eye on you."

"Deedee is one with-it girl. But I guess it's time to tell the truth. Gina and I work for Vanguard Mining, just as we said. We don't work for Operations, though. We work in Security. We were assigned to tag along with your group because there was word of a possible saboteur. The problem was, we had no idea who it might be—you, or Deedee, or Alice, or Vido, it could have been anyone. Actually, our first clue that it might be Alice came from Turkey Gossage."

"Did he see her doing something?" Rick was beginning to suspect that he was the only blind person in the Solar System.

"Not in the usual sense. He had been reviewing her test results, and he noticed that she always scraped through with a score just a few points above the pass mark. That can happen a few times by accident. But if it happens *consistently*, that's unnatural. It suggests that the person taking the test really knows the right answers, and is deliberately giving enough wrong ones to keep her down in the pack. Scraping through was intended to make Moira Lindstrom inconspicuous. Thanks to Turkey's experience and shrewdness, it had the opposite effect.

"That gave a starting point. But of course it wasn't anything like proof. It

could have been just a statistical fluke."

Jigger had been studying Rick as they talked. He had noticed the yawns and the drooping eyelids.

"Rick Luban!" And, when Rick jerked to attention, "You don't realize it, but you've had more shocks than a person can stand in one day. Stress exhausts more than anything. We still have a lot to talk about, but we won't do it tonight."

"The other group, with Barney. . . ."

"Will still be there in the morning."

"I can't possibly go to sleep. Everything inside my head is a big jumbled-up mess."

"I'm sure it is. But you need rest." Jigger pointed across to his own bunk. "I'll tell you what. Stretch out on that for a little while. If you're still awake in ten minutes, you can get up again and we'll talk some more. But it's my bet that you'll fall asleep."

"I bet I don't. I can't possibly sleep." Rick went over to the bunk, lay down on it, and reluctantly closed his eyes.

He lost his bet with Jigger by eight and a half minutes.

CHAPTER NINETEEN

Rick emerged from a vivid nightmare, a chaos of screams and free-fall darkness and bursting bodies. He came suddenly awake, opened his eyes, and sat up.

He stared around him. He was not in his own familiar cabin. When he realized where he was, he knew that part of the nightmare was no dream. Alice had died, in an agony of ruptured lungs and exploding air that turned to a fog of ice crystals. Every

other apprentice had come within seconds of that same fate.

He rolled off the bunk and lurched to his feet. His stomach hurt, and he felt drunk or drugged. How long had he been asleep? Where was everyone else?

There was no sign of Jigger Tait, although it was his room. Rick went outside and staggered along the darkened corridor to the dining area. Everywhere seemed oddly quiet, with the hushed silence of a hospital or a church. All Rick could think of was a drink. His throat was parched and his tongue felt like a withered lump of flesh in his mouth.

He walked into the bright room, squinting his eyes against the sudden light. Only after he had bent over the spigot and allowed cold water to run into his mouth and over his whole face did he take any notice of the people at the tables.

There were three of them: Deedee Mao, Vido Valdez, and Polly Quint were sitting with drinks in front of them, but they were not talking to each other. All of their faces had a pale, waxen look.

Rick moved unsteadily over to them and slumped onto a hard chair. "What time is it? I mean, is it night or morning?"

"Half and half," said Polly. "It's the middle of the night. We've tried but we haven't been able to sleep. Even after Barney's explanation, we can't decide what really happened."

"I wasn't there with Barney." Rick paused. Was he ready to talk about this? "But I was there when Alice died."

"Moirá," said Deedee. "That's what Jigger Tait called her. But I'm like you, I can't think of her any other way than Alice."

"And twenty-six years old." Vido shook his head. "First time I saw her, I guessed she was thirteen. She could have passed for it, easy."

"How *did* she die?" Polly asked. "Barney didn't actually say."

"Jigger killed her." Rick felt obliged to add, "In self-defense. And I almost screwed that up, and killed all of you."

While the others stared, everything came blurting out. Rick made no attempt to excuse his own naiveté and incompetence. The others did not offer a word of criticism, though he knew it was well-deserved. They didn't seem in the least surprised that Rick had been seduced by Alice, and it turned out that Gina Styán had already told them that she and Jigger worked for Vanguard Mining's security office.

The surprise was on Rick's side, when after describing Alice's terrible death he said gloomily, "The rest you know. Jigger didn't come right out and blame me for getting in the way, but I'm sure he thought it. I guess you can cross my name off the short list for exploring the moons of Jupiter."

The other three exchanged looks. "Jigger didn't tell you?" Deedee said.

"Tell me what?"

"That the whole thing was a setup. Security knew there were information leaks somewhere in Vanguard. The people from Avant Mining had been finding out about valuable asteroid discoveries made by our surveys, and flying out there to stake claims before

we did. So Security planted stories, different ones in different places. Then they watched to see what Avant did. And Avant took the bait on this one."

"You mean the Jupiter moon exploration—"

"Isn't real," said Polly. "Not a word. And I had my heart set on it."

"Yeah," Vido snorted. "You and everybody else. Move over, lady."

"Outer System exploration will happen, maybe in another ten years," said Deedee. "It won't be those moons, though. So far as Vanguard's remote surveys can tell, the lesser moons of Jupiter are just big useless lumps of rock. But Gina has been monitoring the shipping records, and a few days ago three of Avant's main prospecting vessels went whomping out through the Belt at maximum acceleration—heading for Jupiter."

"Pulsed fusion, two-and-a-half *g*'s on and off every few seconds," Vido smiled with vicious glee. "Serves the bastards right. Let's hope it takes 'em a long time to get there and longer to come back."

"No Jupiter project." Rick leaned forward and rested his head on the table. "What else have we been lied to about? I've had it. I say screw Avant Mining, and screw Vanguard Mining, and screw everything. We'd be better off in the Pool, back on Earth."

"Amen," said Vido.

The other two seemed to have nothing to add, and after a long pause Vido stood up. "Well," he said, "I've been to bed twice, and I've got up twice because I couldn't sleep. I'm going to take another shot at it. Third

time lucky. Good night, all."

"Wait for me." Polly dragged herself to her feet. "Anything you can do, Vido Valdez, I can do better."

Rick and Deedee were left alone at the table. He did not speak or lift his head, and after a while she sighed and stood up. "Maybe they have the right idea. I'm going to give it a try."

She began to leave the table, then reached across and gently ruffled Rick's hair. "You too, hero. That's what Barney and Gina told us you are, even though you don't think so. Jigger says you saved everybody. Better get used to fame."

She was at the door before she turned and spoke again. "One other thing you may have missed. Barney says that a day to get over shock is the maximum allowance when you work for Vanguard. She told us the party is scheduled for tomorrow night, come meteor shower or solar flare. And it's going to take place the same as before, in the smelter. Still want me to give you dance lessons?"

She waited. Rick did not speak or move. Finally Deedee shook her head and said, "Why don't you sleep on it? But do it in your bunk and not here. Even a bonehead deserves a softer pillow than a table."

And she was gone.

Morning was not pleasant. But it was tolerable, as the middle of the night had not been tolerable.

Work helped. For reasons either therapeutic or punitive, Barney French drove the apprentices as never before. She piled on cleaning chores and exercise fatigues and mainte-

nance details with a vicious disregard for human limitations. Rick reeled through the day from one assignment to the next, without time to rest or think or even eat a proper meal, until a general siren sounded. He realized with astonishment that it was the signal to down tools and head for the smelter.

All for a stupid party.

Rick felt that he wanted nothing in the world less—until he reached the racks at the exit port and saw his suit. He stared at it with a distaste that bordered on horror. More than avoiding a party, more than anything, he did not want to put himself inside that suit and drift through open space to the SM. His mind flung at him a vivid image of Alice, face plate smashed, limbs contorted, dying in the airless void.

He was still standing and staring when Jigger Tait and Gina Styan arrived. They did not notice—or chose to ignore—his frozen immobility.

"This is a bit of luck," said Jigger. "I've been wanting a quiet word with you all day, but Barney told me she had you fully scheduled and I was to stay out of your way. Let's take five minutes when we get over to the smelter, all right?"

It was easier to go along than to admit the truth. Rick found himself climbing lethargically into his suit while he read the sign on the wall.

You may feel SICK, you may feel SAD, you may feel STUPID. . . .

He felt all of those, as well as scared. But he followed protocol, and together with Jigger and Gina performed the thirty-six point check of the suits. That ritual somehow helped.

They went into the airlock together, and he floated across to the smelter with one of them like a guard on each side of him. In the pressurized second hatch of the SM's airlock, Jigger halted.

"You go through, Gina," he said. "Rick and I will get rid of our suits and stay here for a few minutes. See you later."

He motioned Rick to the chamber off the side of the room and followed him in.

"You may wonder what the hell this is all about," he began, even before the door was closed. "I'll get to the point right away. I want to talk about your future. I know how it is at this stage of your training, because I went through it myself. You feel as though the assignments and tests will go on forever. But they won't. They'll be over before you know it. So I want to ask, what do you see yourself doing afterwards?"

"Yesterday, I thought I might have a chance at the Jupiter expedition. Early this morning I was ready to call everything quits and go back to Earth. Now?" Rick shrugged. "Now I don't know what I want."

"I understand about the Jupiter moons. That story paid off for Vanguard, but no one thought through what the effect would be on your group. I can't change that, but I can tell you that even if the Jupiter expedition were real, it still wouldn't be the toughest job in the Solar System. Do you know what is?"

"I guess I don't. All through training we've been told that the most challenging job is out here in the Belt,

mining and refining and carrying finished products back to the Earth-Moon system. Are you saying that's wrong?"

"That's a tough job, and a rewarding one. Almost all the apprentices will be doing some piece of it. For you, though, I want to suggest an alternative. I want to ask you to consider a career with Security."

The idea caught Rick totally unprepared. "Security?" He stared at Jigger. "Why me?"

"I think—and Gina and Barney agree—you probably have a talent for it."

"But I don't know a thing about security operations."

"Of course you don't. You'd have to learn new things. But that will be true wherever you work. Education isn't like a video, with a beginning and a middle and an end. It has a beginning, then it keeps going until you're dead. If it stops you are dead, even if you don't know it. And Gina and I will be learning, too. Vanguard is about to start a completely new project, tougher than anything we've ever tackled before. We'll need all the help we can get."

"You mean—Avant Mining?" Rick thought he knew where Jigger was heading.

"There's certainly opportunities there, if that interests you. Beating Avant won't be easy. They draw their people from the school system's absolute cesspools, the hardest, most cynical kids they can find. You only met one of them—Alice Klein—and she was nowhere near as bad as some of the others. Compared with them, the toughest of your group is Mr. Nice

Guy. But I'm going to surprise you: the hardest job isn't fighting Avant. It's a job where Avant and Vanguard are in total agreement about what needs to be done, and will probably have to join forces to do it. Know what it is?"

Rick shook his head. Vanguard and Avant, working together? He couldn't imagine any area where the two companies had a common interest.

"In fact, if we don't cooperate," Jigger went on, "I don't think we can possibly win. We have to fight a monster that's effectively immortal, a monster with a billion arms, one with a million times more power than Vanguard and Avant combined. A monster not in space, but back on Earth. Do you remember what it was like in school?"

"Very well." Rick's confusion had become total.

"Do you think you're smarter now than you were then?"

Rick had to consider that. He wasn't sure what Jigger was asking. "Smarter, no. My brain's the same. But I know a lot more, and I understand more of what I know."

"Very true. And do you know *why* that's true? I'll tell you. Back on Earth you were being strangled by the biggest, most inefficient, best entrenched bureaucratic system in the history of the world. You were in school, adrift within an education system that had lost any interest in the value of knowledge, or truth, or discipline, or self-evaluation. Like all monopolies, it was more interested in perpetuating and protecting its own territory than in anything else. The

men and women who emerge from the school system know less and less—and then wonder why they find themselves unemployable." Jigger paused. "My God, I'm starting to spout the official company line. Let me get to the point. For every bright bored kid like you who gets kicked out of the system, another thousand stay inside it and are stifled for life. We have to change that. The toughest job in the Solar System isn't on the moons of Jupiter. It's not beating Avant Mining. It's back down on Earth."

"No!" Rick finally thought he knew where Jigger was heading, and for the first time since Alice's death he was flooded with powerful emotion. He saw in his mind Mr. Hamel, the patient turtle, bowed down by thirty years of frustration and indignity. "If you think I could ever go back there and put up with all the bullshit—"

"You told me that early this morning you were ready to go back. But this would be different. Forget the way we operate today. We're talking something a lot more direct. We have to infiltrate the education system, and either transform it or destroy the whole mess. That needs older people, like Turkey Gossage and Coral Wogan—they've both volunteered—but we also need younger people, too, like me and Gina and—"

"No. Absolutely no. I'm not interested." Rick backed toward the door. "I don't want to talk about it any more."

"All right." Jigger nodded and sighed. "I thought you would say that. I've had my five minutes, and more. The party and the dance will be start-

ing now, and you've earned the right to be there. I didn't expect you to say yes, you know. I just wanted to plant the seed of an idea that might grow into something five years from now. Any questions before you go?"

"No." But Rick paused. "Did you ask anyone else in our group?"

"Two other people. I spoke with Vido Valdez, and Gina spoke with Deedee Mao."

"I see. Can you tell me what they said?"

"Yes. Vido told me no way—no goddamn way, to be precise. Deedee told Gina, no, never, not if she lived to be a thousand. Then she asked if we had asked you. Gina told her we had not, but I was going to."

"I see. Thank you. May I go now?"

"Sure. Have fun. I'll be there myself in a few minutes."

Rick closed the door and entered the second chamber of the airlock.

He went through, but at the inner hatch he paused and stood motionless for a long time. He had not thought about Mr. Hamel for months, until today; but suddenly his mind was full of their final meeting, the small stooped figure sitting on the bench in the fading light of late afternoon. He heard again that dry, dusty voice: *Not an easy job, but a worthwhile one. The most rewarding jobs are always the most difficult ones.*

Could that be true? On Earth, in space, everywhere?

Maybe; but not for Rick Luban. Not tomorrow, not ever. And certainly not today, with Deedee waiting for him.

He moved to operate the hatch.

Beyond it, the party was getting into its stride. From where Rick was standing the sound through the closed door was no more than a confused hubbub, like the first distant swell of a revolution. ■

So much has already been written about everything that you can't find out anything about it.

—James Thurber

To treat your facts with imagination is one thing, but to imagine your facts is another.

—John Burroughs

It is a miserable state of mind to have few things to desire, and many things to fear.

—Francis Bacon

Don D'Ammassa

ORWELL'S OTHER NIGHTMARE

It was a bright cold day in April, and the clocks were striking thirteen. Marlboro Smith surveyed his desk with satisfaction. The monthly reports were done and he'd responded to all recent requests under the Public Accountability Act. His workload was current once more.

Smith enjoyed being a public employee, even though he knew he should be ashamed of that fact.

He carefully assumed a pained expression and turned toward the omnipresent Public Oversight camera. It was mounted to look over his shoulder so that it could record exactly what Marlboro wrote, read, or filed away. The placard beneath the lens warned:

LITTLE SISTER IS WATCHING YOU.

Smith sensed someone standing just outside his office. There was no door; no government official had worked behind a closed door since the Governmental Scrutiny Amendment's ratification.

"May I help you?"

Discovered, the other man entered, his expression one of undisguised distaste. "I'm here in an official capacity, Bureaucrat Smith."

"But I've already been audited this month!" He protested without hope. Under the Federal Reorganization Act, all government functions were divided among Central Services, Implementation, and Administrative Operations. Each agency was obligated by law to monitor the others.

"We've had a complaint."

Smith felt his stomach clench. "What kind of complaint?"

"Bureaucrat Myrtle Dagosian reported that you said to her, and I quote, 'We *ought* to do something about the inefficiency around here.' Is that an accurate version of your remark?"

He hesitated. Obviously his visitor was an agent of the Ought Police, devoted to suppressing any secret wish to transfer power from the people to elected or appointed officials.

"Yes, I did. But the pronoun 'we' referred to the American public and not my official position, Mr. ...?"

"O'Brien." The interloper appear dissatisfied. "Is your desk always this clean?"

"Well, I can't stand disorder."

"Have you caught up to your workload?"

Smith saw the trap. "Of course not, I've just placed it in a drawer. Catching up would imply excessive intrusion into the public realm."

"Are you aware that you have the highest efficiency rating in Washington?"

"My predecessor cleared things up during the transition. When I arrived, there was no backlog. I've been much less productive."

O'Brien nodded skeptically. "Your attendance is also extraordinary. An excess of zeal is cause for disciplinary action."

"I'm an early riser and I catch the early train to avoid the crowds. If you check my lunchbreaks, you'll find that I'm rarely punctual about returning, and I frequently leave early."

"You could wait outside, smoke a cigarette."

"But smoking is illegal!"

"The rule of law is a rule of crime," O'Brien quoted. "A healthy disrespect for intrusive regulation is the mark of a true patriot."

"I guess I never looked at it that way. The price of freedom is eternal vigilance."

O'Brien left shortly thereafter, leaving Smith distinctly unsettled.

EFFICIENCY IS WASTE.

The banner was draped across the elevator lobby. Smith waited impatiently. He considered himself a patri-

ot, knew that the government that governed the least governed the best. But it was hard to let things slide. It was an unspeakable crime but in the secret recesses of his mind, Marlboro Smith knew he was guilty.

He loved being a government employee.

There was a new lobby placard the following morning.

GOVERNMENT SERVICE IS A CONTRADICTION IN TERMS.

O'Brien was waiting in Smith's office.

"Good morning, Citizen O'Brien. May I be of limited assistance?"

"I'm here to issue you a writ of mandatory refresher training."

"Refresher training?" Smith was bewildered. "But I thought everything was in order."

"I reviewed your present and prior performance. You were demoted after several warnings about a high intrusiveness rating, and one violation of the Limited Implementation law."

"I was just trying to help!" Smith responded emotionally. "There were conflicting rules and the state agencies kept contradicting each other. The disaster victims needed assistance and invoking federal jurisdiction was the only solution."

"So you concluded that a government official had the right to determine the future of American citizens."

"Not exactly. I was trying to fulfill their requirements of the government."

"Your superior didn't see it that way."

"Molinski didn't understand that

the federal statute took precedence.”

“And you did?”

“I consulted legal experts first.”

“You feel justified then?”

“Yes.” Smith froze, realizing he’d just indicted himself.

O’Brien smiled. “Bureaucrat Smith, you have just admitted believing that official action can have positive results rather than being a necessary evil. I will therefore recommend your immediate suspension pending mandatory attitude adjustment therapy.”

Fury swept away the last vestiges of Smith’s reserve. “All right, I admit it. I love my job. Why should that be a crime? I’m trying to help. That’s what government should do.”

“That’s the kind of thinking that made America lose sight of the fact that central authority necessarily strips away freedom.”

“But nothing ever gets done now! Government service is the career of choice of the inept, the incompetent, and the indolent. We need to reshape

government to reshape our future.”

O’Brien scowled. “You want to know what the future holds for government employees, Smith? I’ll tell you. Picture a giant glove, ripping your balls off forever. That’s the future, Smith.”

Six weeks later, Smith was released from retraining, wearing a graduation pin that said “Order is Chaos.” He returned to his job the following day, showing up fifteen minutes late, sorted all of the paper on his desk into four priority piles but failed to deal with any of them lest he interfere with some citizen’s freedom to sicken and die, or starve, or infringe on a neighbor’s rights. After his two hour lunch, he carefully polished the lens of the Public Oversight camera, and noticed with satisfaction that he no longer had to fake his smile when he looked in that direction.

He had won the victory over himself. He loved Little Sister. ■

It is very hard to extract the nucleus of truth from things that just aren’t so.

—Will Cuppy

The relation of genius to talent is the same as that of instinct to reason.

—Jules Renard

The larger the island of knowledge, the longer the shoreline of wonder.

—Ralph W. Sockman

Memento Mori, Shariann Lewitt, TOR, \$21.95, 286 pp. (ISBN: 0-312-85625-3).

The Golden Nineties, Lisa Mason, Bantam, \$12.95, 371 pp.

(ISBN: 0-553-09503-X).

Tech-Heaven, Linda Nagata, Bantam, \$4.99, 358 pp. (ISBN: 0-553-56926-0).

The Godmother's Apprentice, Elizabeth Ann Scarborough, Ace, \$19.95, 292 pp. (ISBN: 0-441-00252-8).

Women of Wonder: The Classic Years, Pamela Sargent, ed., Harcourt Brace, \$15, 440 pp. (ISBN: 0-15-600031-4).

Women of Wonder: The Contemporary Years, Pamela Sargent, ed., Harcourt Brace, \$15, 422 pp. (ISBN: 0-15-600033-4).

Voices for the Earth, Daniel D. Chiras, ed., Johnson Books (1880 S. 57th Court, Boulder, CO 80301), \$16.95, 248 pp. (ISBN: 1-55566-146-7).

Terraforming: Engineering Planetary Environments, Martyn J. Fogg, Society of Automotive Engineers (400 Commonwealth Drive, Warrendale, PA 15096-0001), \$49, 544 + xvi pp. (ISBN: 1-56091-609-5).

Higher Superstition: The Academic Left and Its Quarrels With Science, Paul R. Gross and Norman Levitt, Johns Hopkins University Press, 1994. (ISBN: 0-8018-4766-4). [Review by Rick Cook]

More than any other disease in recent history, Acquired Immune Deficiency Syndrome (AIDS) has stirred passions and the urge to memorialize. Why? It is death spread by activities that affirm life (sex and blood and organ donation) as well as by addicts sharing needles. It struck first at male homosexuals, a group that already was so discriminated against that in an age of fairness the disease seemed particularly unfair (though there have certainly been enough reactionary comments along the lines of "AIDS is God's judg-

ment on queers" to make it clear how dark and dirty a secret it would have been a century ago). It has claimed a large share of society's best and brightest, including many in the arts. And it continues to defy all efforts to find a cure, though it seems quite easy to avoid it: just keep your noses (and other parts) clean, and rinse your needles out with dilute chlorine bleach before you pass them on.

We haven't yet commissioned in memoriam of the AIDS deaths bronze or granite monuments as we have for wartime deaths, or enshrined piles of

shorn hair as we have for the Nazi death camps, or put racks of skulls on display as we have for the Cambodian killing fields. But perhaps that time will come, for the memorializing urge is there. We want to atone for all that monstrous unfairness, so we make thousands of quilts. We hold marches and bake sales. And some of us write novels such as Shariann Lewitt's *Memento Mori*.

Is the book really about AIDS? Consider: On the colony world of Reis, successful and prosperous, a virus has appeared. The symptoms include blue splotches on the skin (reminiscent of Kaposi's sarcoma, seen in AIDS patients) and wasting (in Africa, AIDS is known as "slim"). How it is spread, its "vector," is not known, but it seems to strike everyone, with the notable exception of the posturing artists *manque* who cluster about the Metz tavern to talk of how famous they will someday be—if they ever do anything and if the world recognizes their brilliance—and drink the licorice-flavored Jaegermeister.

As the plague spreads, the world is quarantined from its neighbors, and the city is quarantined from its hinterland. Performance artists begin to blow up buildings and stage public suicides as a form of "terminal art" (death is the coming thing, you know). Inspired, the Metzians name themselves "Metzhaus" and begin to seek their own ways of turning death to art, though of course in a much classier way.

Complications abound, for the city is ruled by RICE, an artificial intelligence built in part of DNA and hence, says Lewitt, much more alive than

mere mechanism. Something unspecified has sabotaged its internal coding to drive it out of perpetual, biddable infancy into troubled, defiant adolescence. One of the Metzians is Peter Haas, a chess master scheduled to play the precocious Senga Grieg, who has been sharing with RICE—via full sensory link—her obsession with martyrs and pain. There is a hint that Lewitt thinks disaster should be encouraged, for only thus can the species advance. There is another hint that she thinks humanity itself is close kin to a virus, and that its spread into the Galaxy may be best likened to an infection: The paths of humanity's expansion into the Galaxy are called "Vectors," and vectors are what spread plagues.

This is an interesting, thoughtful book. The major characters—especially RICE and Jens, the ex-street waif who pretends to membership in the clique of university-bred pretenders—are well drawn. Events have a fair amount of inevitability. And the sense of futility that imbues the book is perhaps the best possible reflection of the mood that surrounds AIDS in the real world.

Yet I found that futility excessive, far too *fin de siècle*. The end of the century is upon us, and SF has in recent decades turned critical of the technological enterprise, but SF is at root an optimistic genre. Certainly, optimism is a large part of the *Analog* spirit.

On the other hand, it's hard to be optimistic about AIDS.

Lisa Mason's *The Golden Nineties* is the sequel to her acclaimed *Summer of Love*. Yet it is not—it couldn't

be—a sequel in the conventional sense that it continues the story of time-traveler Chiron Cat's Eye in Draco and his visit to the free-speakin', rockin', dopin' San Francisco of 1967. Mason wrapped up that tale very well. But she had created a 25th century world of overpopulation (rebounded from a disastrous period in our nearer future) and environmental crisis, with additional crisis stemming from time-travel's (or tachyportation's) disruptive effect on the timeline.

Golden Nineties is the tale of Zhu Wong, a Chinese woman with gene-tweaked green eyes who as an anti-birth activist has attacked an illegal birth clinic and assaulted a child. She is awaiting trial—for murder, if the child dies—when Chiron Cat's Eye in Draco's tachyportation institute drafts her to visit the 1890s, meet Wing Sing, a Chinese maiden who possesses a particular bit of jewelry (an "aurelia"), and steer her to a certain shelter, all to ensure that an old Chinese woman should exist to hand Chiron the aurelia in 1967.

Of course, the mission goes wrong almost immediately. Wing Sing appears on schedule, but she does not have the aurelia and before Zhu can get her to shelter, tong enforcers seize them both and haul them off to a life of prostitution, the almost inevitable fate of the very few Chinese women to be found in the California of the time. Fortunately, madam Jessie Malone rescues Zhu, who becomes the book-keeper for Jessie's cribs and houses.

Zhu also meets Daniel Watkins, who has come to Californ' to fore-close on some of his father's defaulted

real estate loans. They become lovers, even though Daniel is quite fond of the bottle and falls into the grip of cocaine as soon as it is offered him as a "cure" for dipsomania (yes, kiddies, cocaine and morphine were legal in those days).

Zhu continues to hunt for the aurelia. She tries again and again to rescue Wing Sing. But Wing Sing, whose feet were normal at first encounter, now has bound feet. She is crippled, and she wants no intervention, thank you. Then her feet are normal once more, and. . .

What is going on? Time is malleable. Reality is in flux. That is the problem Chiron and his colleagues fear most, but it is also a way for Mason to underline her point. California's golden nineties were a hotbed of extreme racism and sexism. The Chinese were viewed as little better than animals. They were not allowed to bring their families with them for fear of a vigorously breeding "Yellow Peril." The few Chinese women who were smuggled in were slaves and whores, but black, red, and white women were often little better off, for women were a commodity, valued only for one thing.

So what else is new? Well, of course, it's an old story. But the nineties were also a time of extreme ferment. Women's suffrage was on the horizon, and indeed Jessie Malone's black housemaid attends suffrage meetings. Perhaps Mason's fluxing of timelines is only a metaphor for the fluxing of mundane reality, of civil rights and women's rights and human rights. Certainly she uses it in her deliberately ambiguous conclusion to the novel to tell us that

the worst of all possible outcomes are not inevitable. One can make choices that save us from disaster and ensure something very like a happy ending.

As I said last time, Mason has an astonishing gift. Her chief characters live and breathe convincingly, her themes are as significant as anyone could wish, and I expect this book to win as much acclaim as its predecessor.

With a bit of luck, she will gift us with many more.

Linda Nagata's second novel is an excellent portrayal of how nanotechnology may one day penetrate human society. Yet **Tech-Heaven** is not at all the same as her first, *The Bohr Maker*. That was a frantic rush through a world transformed by nanotech. This shows us a world that has not yet reached that point, though it may be close. It opens with sixty-four-year-old Katie Kishida riding a VR-controlled robot into the Andes. She is fleeing "Voice cops" and seeking a cavern in which, many years before, she had helped to hide the cryonically preserved bodies of her husband and others from the interference of pro-"natural," anti-biotech bigots. At a small store, she picks up a package she had had mailed to herself. In it there is a way to awaken her husband. The cops are after her because it is illegal.

So we know where the story must go. But first Nagata must show us how it got that far. Meet Katie long years before, learning that her injured husband is about to die. She calls the cryonics company and has him frozen despite the objections of the surgeon and her sister-in-law, Senator Ilene Car-

son. The rest of the family, though surprised, comes around; Ilene does not. In fact, Ilene becomes the head of a political movement out to ban such wastes of resources as life-extension research. Eventually—no surprise—she becomes the head of the Voice, an organization, based in orbital habitats, that aims to prevent technological changes that might change the "human condition" and is rapidly superseding ground-bound national governments. Meanwhile, Katie goes on with her life. One daughter goes into nanotech research. Katie marries one of the cryonics folks and becomes involved in beating the drums for life-extension work. The antis gather momentum. But nanotech is developing. There is hope, and in due time the two forces must collide head on.

I simplify immensely. Nagata has woven a complex, poignant tale out of one woman's grief and loss and obsession, showing very well how one may move on yet still be yanked back to old loves and commitments. If the model for so much SF adventure is the old-timey "horse opera," the model for this one is the soap opera.

Sort of, anyway. And perhaps enough so that those who find ordinary SF a bit too much concerned with gadgetry and too little concerned with the human heart will love *Tech Heaven*. Its greatest weakness—Nagata's bow to the conventional view that people can't be *really* dead (Katie's husband has to dream, even if he does have the consistency of a chunk of granite) and still be revived—may even be a plus for such readers.

* * *

Elizabeth Ann Scarborough's **The Godmother's Apprentice** is the sequel to *The Godmother*. Unfortunately, though it is charming enough and quite skillfully done, it does not live up to expectations raised by its predecessor.

Godmother gave us a Seattle beset by problems of a sort the Brothers Grimm would have loved, and in it she set mixed up retakes of a number of old fairy tales. Snohomish Quantrill was a combination of Snow White and Little Red Riding Hood whose wicked stepmother wanted her dead. Hansel and Gretel were there too, though their witch was male. There was even a fairy godmother, Dame Felicity Fortune, out to rescue as many waifs as possible. The result I called "a great deal of very pointed fun."

The fairy tales are still there in *Apprentice*, but the point seems blunted. The scene is Ireland, where Dame Fortune has taken Sno to be trained as a godmother. There are fairy mounds and talking swans and house sprites and pookhas and figures out of Irish legend. There is Jack, a tinker lad whose demented Mam has wandered off in pursuit of the King of the Cats' funeral procession, which must cover the length and breadth of the Emerald Isle. There is a maiden whose wicked aunt foretold her doom; she is fleeing murder and being pursued by an agent of the Irish terror.

Upon her arrival, Sno is equipped by the Godmothers' sorority with a little golden box containing the traditional three wishes. Quite inadvertently, she uses the first wish to gain the ability to talk with animals. This

ability proves invaluable as Jack, swans, cats, maiden, and terror converge for the obligatory scene of triumph and redemption.

Why is *Apprentice's* point so blunted? Perhaps it is the *explicit* presence of Faerie here, which disconnects the tale from the real world in a way that did not happen in *Godmother*. Perhaps it is the Irish setting, which makes the point seem more distant for an American reader than it must seem for an Irish one. Perhaps it is just that Scarborough had done it so well before that *Apprentice* seems mere repetition. If this last is the case, we may regret that the tale's end shows every sign of leading into another sequel. If the problem is mere setting, it may vanish, for Sno is returning home to the States. If it is explicitness of Faerie, let us hope that two points do not plot the trend.

Back in the seventies, Pamela Sargent edited three anthologies—*Women of Wonder*, *More Women of Wonder*, and *The New Women of Wonder*—that proved quite influential in promoting awareness of the women who have helped to shape SF and in bringing more women into SF as readers and writers. She has now reprised those anthologies with **Women of Wonder: The Classic Years**, which reprints a number of stories from them and adds others from the same pre-seventies time period, and brought them into the present with **Women of Wonder: The Contemporary Years**, which offers stories written since 1978.¹

Like its predecessors, *Classic* is a

salutary reminder of the part women have played in SF. Here is a firmament of stars, many of them more memorable than the men who—sometimes reluctantly—shared the magazine pages with them: C. L. Moore, Leigh Brackett, Zenna Henderson, Marion Zimmer Bradley, Anne McCaffrey, Joanna Russ, Kate Wilhelm, James Tiptree, Jr., Ursula K. Le Guin, Joan Vinge, and more.

Sargent puts herself (with justice) among the stars of *Contemporary*, including C. J. Cherryh, Tanith Lee, Suzy McKee Charnas, Octavia Butler, Sheila Finch, Pat Cadigan, Pat Murphy, Connie Willis, Lisa Goldstein, Nancy Kress, and Rebecca Ore, a roster that is quite enough to justify Sargent's comment that "[I]t is no longer possible to discuss science fiction without mentioning the women who have contributed to it. Conversely, it is also impossible to give an account of women science fiction writers and their work without discussing the genre as a whole. The topic of women and science fiction is not an ancillary topic anymore, one to be set aside from the history of the literature as a kind of sidebar or footnote; to discuss women and science fiction is, of necessity, to discuss the entire field. Perhaps eventually, if sexism and racism diminish sufficiently, we may finally discuss only writers." (p. 16)

She takes a step in this direction when she says that her "purpose [in these anthologies] is to present

thoughtful, entertaining, well-written science fiction by women in which female characters, human or alien, play important roles. Although some stories are likely to strike the reader as feminist in tone, no ideological ruler was used to measure them for selection. One of my goals is to present stories that reflect the variety of different literary paths women have taken in writing science fiction and the varied imaginary worlds they have created. This requires including stories that some may see as pre-feminist, post-feminist, or not feminist at all." (p. 19) That is, the feminist "agenda" provides the occasion for the books and the excuse for putting their stories in a single package. Beyond that, ideology is secondary.

Do you want these books? That's the wrong question. If you still think of SF as male turf, you *need* them. So do those young women of your acquaintance who shun SF because they think it's for boys. For their sake, I'm going to give my review copies to the local middle school.

The latest (as I write this) issue of *Science*, the journal of the American Association for the Advancement of Science, contains an alarming line: "Many House Republicans dislike [NASA's Earth Observing System program] both for its expense and its environmental focus. . . . [T]hey fear the results could lead to more regulation of the environment." The missing step in the logic is the idea that studying the environment can identify problems, perhaps in time to do something about them, and that we will of course try to do that some-

1. Drawing the line between classic and contemporary at 1978 is enough to make me feel like quite an antique!

thing, i.e., attempt to regulate the actions of voters and campaign-contributing businesses.

Why is the step missing? Probably because most voters would think it a fine idea to keep an eye out for problems that will lead to their own illness and death (which a great many environmental problems can do). Many businesses would rather not know, for fixing problems can be expensive. It's cheaper to buy a politician. Just ask the tobacco industry.

Where am I going with this? I have before me **Voices for the Earth: Vital Ideas from America's Best Environmental Books**, edited by environmentalist professor and textbook author Daniel D. Chiras of the University of Denver. Its premise is that we are in trouble and that we need to find a way to exploit the environment in a sustainable way. The readings come from such books as *Beyond the Limits*, *State of the World*, and *Confessions of an Eco-Warrior*. The voices are alarmed and reasonable or alarmed and unreasonable, but always alarmed. The problems are real, they insist, and we really must take steps.

If you haven't wanted to spend the money to buy a shelf full of environmental "alarmism" but would still like to see what there might be to be alarmed about, this is an excellent survey.

Another kind of "voice for the Earth" is Martyn Fogg's **Terraforming: Engineering Planetary Environments**. The topic has obvious connections with SF, but there are a number—20 to 30, says Fogg—of university and government researchers,

here and abroad, who have paid serious attention to it. Their papers, along with Fogg's own reports, published in the *Journal of the British Interplanetary Society*, Stephen Gillett's articles in *Analog* (and elsewhere), and more form the basis of Fogg's book.

After surveying the history of the basic idea in and out of SF, Fogg gets down to cases by considering the nature of biological life-support systems and what this must entail for maintaining existing systems such as Earth's or constructing new ones, as on Mars. He presents the view that humanity has already established itself as a planet-reshaping force and says that if we add intent to that, the next step is easily seen as the greening of places like Mars. He then analyzes various proposals for modifying Mars, Venus, and other worlds (and worldlets) so that they become able to support life, even including human life. He does not duck the scale of such projects, and he admits that in no way can we expect to remake a world in less than millennia, putting "overnight" terraforming in the category of "urban myth."

The technologies he sketches are grandiose in a way familiar to SF readers and writers. Yet they are firmly based in the laws of chemistry and physics and orbital mechanics. He lays it all out in a way that must bring joy to the heart of anyone (SF writers take note) who craves a terraforming reference book. Yet he does seem to overlook the obvious; his focus is the remaking of entire worlds, with the aim of letting people live in the open. As an intermediate stage he mentions the

possibility of a "worldhouse," a planet whose atmosphere has been confined beneath a roof set on three-kilometer-high towers. He grants that such a thing must start small and grow, but he mentions only briefly and dismissively the possibilities inherent in "parateraforming," the containment of small biospheric volumes. On the largest scale, this means worldhouses; on smaller scales, it can mean roofing valleys and craters, doming settlements, and burrowing beneath the surface, even hollowing out moons and asteroids. I cannot help but feel that there is more promise here than Fogg is willing to grant.

Why should we even talk about such things, much less actually do them? The talk—the research and planning and thought-experimenting—is worthwhile because it gives us a perspective on the Earth and what we must do to maintain it that is quite unobtainable in other ways. It also offers a way to bring the many disciplines involved—astronomy, geology, physics, biology—together in a way that aids education.

Should we *do* such things? That is a more philosophical question, and he describes some of the debate over the ethics of revising nature so thoroughly. Strange though it may seem, there are actually people who insist that even barren rocks have a right to exist undisturbed by humanity. They forget that rights are a human invention.

(Review by Rick Cook)

Higher Superstition: The Academic Left and Its Quarrels With Science is a child's garden of lunacy nur-

tured in groves of academe. The subject is science—or more precisely the attack on science by various trendy disciplines.

Unlike the creationist's quarrel with evolution, this attack is broad-based and intellectually respectable. Its central tenet is that rather than the discovery of objective facts, science is largely (or entirely) a matter of social convention—like whether you slurp your soup in polite company.

This notion is politically useful to a great many groups. Some dislike science on principle, some dislike the impact of science on their areas of interest, and some are just tired of seeing their beautiful theories murdered by gangs of ugly facts.

Of course Gross and Levitt, both scientists, single out the usual suspects. There are exponents of "feminist science," the eco-extremists in whose theology science plays the role assigned to the snake in more traditional creation myths, the Afrocentrists with their conspiracy theory of history, the deconstructionists who see science as a "text" to be scribbled over, and the extreme relativists for whom there is no objective truth at all.

What is most interesting about these attacks, as Gross and Levitt point out, is their sterility. It is one thing to say that there are other ways of knowing besides science or other kinds of science. It is something else entirely to produce examples of superior knowledge gleaned from such sources. Like anti-evolutionary biology, the explications of these new principles are mostly attacks on the existing ones. So much so that in both

cases it is extremely difficult to piece together a coherent picture of what these alternatives are supposed to be.

Some of this is simple miscommunication. One of the central problems for the critics is that they are trained to think metaphorically while science emphasizes literality. What the scientist puts forth as a statement of fact the critics take as a metaphorical launching pad. The scientist's objections are seen as niggling by the critic and the critic's output is seen as absurd by the scientist. One result is that the two groups are literally incomprehensible to each other.

Higher Superstition is a book which has gotten itself roundly hated

in certain circles for what is seen as argument by caricature. The charge is unfair. *Higher Superstition* is an angry book, but it does not rely on caricature. Gross and Levitt concentrate on "respectable" scholars who have a position and following within the various movements. They may not be the most temperate examples of their schools of thought, but they occupy a position more nearly analogous to, say, Newt Gingrich than Bo Gritz.

Higher Superstition isn't as much fun as the fiction that is normally reviewed in *Analog*, but it is well worth reading for its study of another kind of "fiction about science." ■

(*Biolog continued from page 101*)

by polished sketches that are faxed to the art director. For space scenes, he then "paints" a two-dimensional planetary surface which he wraps around a sphere, using a 3D program. A similar technique creates spacecraft and other machines. People start out as real models or photographs that are scanned into memory for enhancement, morphing, or whatever techniques that will produce the desired look. He uses a series of graphics programs that he mixes and matches on a PowerMac since no single program exists that is comprehensive enough. For this, 86MB of RAM is barely adequate.

Editor Stan Schmidt is famous for demanding scientific accuracy from his writers. In George, he has an artist capable of keeping the physics right and imparting plausibility to future mechanisms. For this month's

cover, George says it helped that he already knew quite a bit about Jupiter and its interior structure. To work out the look of tomorrow's machinery, such as robots, he uses an analytical approach where form tends to follow function. He thinks when aliens are found on a distant world, their artifacts will follow the form/function principle as well.

George considers it silly that many people still scoff at SF when they are already living in a science-fictional world. Now that *Analog* itself is produced almost entirely using computers, he feels he is completing the final link by furnishing computer-aided art. Like writers typing at a word-processor and editors pushing blocks of type around a monitor, George makes use of the micro-processor as a tool. The operating system controlling that hardware is a uniquely programmed artist. ■

Dear Dr. Schmidt:
This is in regard to Kent Patterson's "Cradle and All," in the August 1995 issue. In one scene the hero Orem is described as using a computer with a ball-shaped device called a mouse. Sadly, the author is no longer available to discuss what I'm about to say. In a larger sense, though, my argument is not with him, but with you, for failing to challenge even a trivial detail. I use the word "trivial" because the computer is seen only once, if I recollect correctly and does not figure importantly in the story.

Essentially, my complaint is that a computer and mouse are anachronistic in this story, and their presence is an example of both authorial and editorial sloppiness that happens too frequently. True, the computer is never described as such. But because the very fact that it is both given a now-popular name, and that a currently used device (the mouse) is mentioned, it's not unreasonable to assume we are looking at something very much like today's PC. Given the present rate of progress of Earth's space programs, the most optimistic dating for the story would be 75-100 years in the future. A more conserva-

tive (realistic?) dating would be two to three centuries hence.

Even if we are talking about only the year 2095, why should we expect the computer to be anything like its current incarnation? A few years ago, you ran a series of stories on a "pocket brain," a hand-held, neurally-connected computer that allowed one person to do the work of many. In a novelette by Orson Scott Card, the words being typed appear holographically above the computer without need of a monitor.

Why couldn't the Cradle have computers with such characteristics? Why should they be called computers at all? While it's true that the basic typewriter keyboard still looks much as it did a century ago, the designation "typewriter" has almost disappeared from everyday use. While we still type, we do so on a word processor or a computer. Why should not both the function and the device used change names further in the future?

And why don't details like this get more attention from editors?

ALAN CLIVE

143 Fleetwood Terrace
Silver Spring, MD 20910

*Sometimes function and name
change as much as you'd think,*

sometimes only one of them does, and sometimes neither. Consider the word "manuscript," for example, which is still generally applied to computer printouts even though no part of the word still applies with its original meaning. You're probably right that things are likely to appear much more different in real futures than they often do in stories, but there's another consideration you ignore. Particularly in a short story, where there's not much room to develop a wildly unfamiliar background, a truly realistic story of the far future would likely be unreadable by a 20th century audience!

Dear Dr. Schmidt:

For the first time in almost 50 years of readership, I am motivated to respond to an editorial. Specifically, "Dedication" (September 1995) dealt with a viewpoint with which I am intimately familiar. California began licensing clinical (medical) laboratories and their personnel in 1937, 27 years before any other state. One of the categories licensed was the laboratory director. Licensure was created for physicians and for the clinical laboratory bioanalyst, the latter being a non-physician, non-doctoral laboratory professional. Under the original California law the bioanalyst was required to have a bachelors degree (later increased to a masters), five years of experience in all phases of clinical laboratory work, and to take a written-practical-oral examination. Only one-third of those taking the exam passed it and were licensed to direct a laboratory. I took the exam in 1958, passed it

and subsequently owned, directed and operated my own laboratory in a small community on the central coast of California. During that period of time I not only directed the laboratory but also performed 50-100% of the actual testing. As new tests, techniques and equipment appeared, I became proficient in them, as did my technologist employees. I am still legally qualified to step in and assume the legal responsibilities for running a full-service laboratory.

The phenomenon you described appeared as far back as 1965, with passage of the Medicare Act. This act mandated that a laboratory director must possess a doctoral degree, either an M.D. or a Ph. D. This requirement was established by an advisory committee to HEW, a panel composed of eastern university academics, influenced by the AMA and the College of American Pathologists. At that time 25% of all clinical laboratories in the U.S. were located in California and one-third of those were directed by bioanalysts. Since a full-service laboratory was defined as one offering services in the disciplines of chemistry, microbiology, immunology, hematology and immunohematology, in order to qualify for Medicare reimbursement the non-physician directed laboratory required five individuals, each with a Ph. D. in one of the disciplines. To further compound the problem, no university in the US offered a program leading to a doctorate as a laboratory generalist. After intensive negotiations, the bioanalyst achieved being "grandfathered" into the Act.

The corporate trend towards spe-

cialization and departmentalization has, in recent years, virtually destroyed the small and medium-sized community laboratory in California. Decreased reimbursement levels from medicare (every year since 1965) has led to the gobbling up of the community laboratory by the large, centralized laboratory corporations. The service aspect of laboratory services has been totally lost. The patient has become a "number," the physician an "account," the nursing and convalescent home an "unavoidable impediment." Required testing is immediately, by default, referred to the local hospital laboratory, where the test charges average 8-20 times higher than the "commercial" laboratory fees.

Specialization, at least in the laboratory field, certainly has led to all of the problems you mentioned—staffing difficulties, job dissatisfaction, lack of career mobility, hiring of less trained personnel to perform a very narrow range of functions, etc. I firmly believe the driving force behind this specialization is economic. The policies of the large laboratory corporations are, for the most part, established by accountants. The sole interest is the bottom line. Decreasing reimbursement levels by governmental agencies (Medicare) and insurance companies, steadily increasing governmental regulations (a paperwork blizzard) and the concept that the automated testing equipment introduced in recent years is "idiot-proof" (have you ever seen a piece of equipment that cannot be made to operate improperly?) are major contributors.

I heartily endorse the last para-

graph of the editorial and find the reference to Lazarus Long (whose observations I have collected) to be most appropriate. As a corollary I would offer the old saying "The Ph. D. is designed to teach the individual more and more about less and less until, finally, the individual knows everything about nothing," but substituting "specialist" for "Ph.D." Will we never learn?

GEORGE P. HIGHLAND

P.O. Box 453
Atascadero, CA

Dear Mr. Schmidt,

As a moderate I believe the truth falls somewhere in the middle of most conceptual arguments. The same is probably true of specialization vs. generalization. But, for a moment, entertain this concept—specialization is a labor-driven goal while generalization is a management-driven goal. The smaller the business, the more visible the concept is in action. While workers like to think of themselves as unique, as having irreplaceable talents, their managers tend to think of them as parts in a machine. It is in a manager's best interest to stroke workers into believing they're unique . . . while at the same time making sure (as is possible) to have "replacement parts" waiting in the wings.

In any case, I see both generalization and specialization as evils at opposite sides of the spectrum. On one hand, generalization invites sloppiness. Seriously, would you want a general practitioner to perform a quadruple bypass on you? While a GP would certainly do his/her best work, would

"best" be "enough" to reasonably guarantee successful surgery? On the other hand, specialization is a monopoly in miniature . . . and the law of supply and demand would guarantee heavy economic burdens on those who require the services of a specialist. In my opinion, specialists and generalists should operate in the same world. Generalists could pick up the slack when specialists are overutilized, and specialists would be our ace-in-the-hole when jack-of-all-trades-but-master-of-none isn't enough to meet our more important needs . . . such as life itself.

J. ALEC WEST

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That's a pretty good analysis. No, I wouldn't want a GP to do a quadruple bypass on me—but very few medical procedures make such special demands as that one, and many can be handled quite well, and in some cases perhaps better, by a generalist. As you indicate, excessive reliance on either generalists or specialists is risky. We need some of both—and the judgment to know when each is appropriate.

Dear Dr. Schmidt,

Gregory Bennett's comments in your Mid-December issue raised a spark of protest, but when I read Steve Moyer's letter in the September issue, I felt compelled to respond. You see, in a sense, I am inside the mosquito box with AIDS patients, because for the past 10 years I have lived in northern Haiti, where there are lots of mosqui-

toes and lots of people with AIDS.

I am a health care worker, of whom Mr. Moyer is glad he is not one, working at a mission hospital whose clinic does about 8,000 consultations a month. We see many cases of mosquito-borne diseases such as malaria and filariasis (the cause of elephantiasis), and also many cases of various sexually transmitted diseases (STD). And in our vast experience with thousands of AIDS cases, it is quite clear that AIDS follows the pattern of STD, and not the more random incidence of a mosquito-borne disease.

As a health care worker, I have also seen that many people are likely to lie, especially concerning their sexual activities. Almost any experienced health care worker can tell stories of a patient who vehemently denies sexual contact, in the face of confirmed STD, or even pregnancy. So I'm afraid that I put the statement "I got it from a mosquito" in the same category as "I got it from a toilet seat."

Living in Haiti, I do try to avoid mosquito bites, because I would like to avoid getting malaria or viral encephalitis. And I admit it's sometimes scary caring for people with dangerous contagious diseases, such as meningococcal meningitis. But I'm certainly not worried about getting AIDS through casual contact or mosquito bites. It just isn't that contagious.

ALTA HODGES

Limbe, Haiti

Dear Mr. Schmidt:

Yea! for "Ben Franklin's Spaceship" by Joseph Lazzaro and Peter Manly (September 1995). It was an excellent

example of a short story that had a situation, a believable solution, and appropriate good guys and bad guy(s). And, the authors did not waste the reader's time with unrelated bits and pieces of description. Sort of the kind of story I wish I could write.

I liked Paul Levinson's "The Chronology Protection Case" except for the lack of electronic submission of the material to the world. Like many real people, the scientists in the story forgot that "publish" can also be in non-hard copy format. What would the Universe do if one of them had written up all the notes along the way with a "drop dead" command set to send the whole works in the realm of Internet (or the like) to a selected list of recipients, if the "hold" command was not given at stated intervals? Everything is still secret, protected, etc. and will still be published if something happens.

In regards to your editorial "Dedication," I happen to be a generalist with a number of "specialized" areas of knowledge. Such things happen when you go to college and graduate school for nine years (combined) and had a father who believed in knowing what you are doing or find someone who does. I was trained as a researcher (definition: "you get paid for looking whether you find anything or not") and have ended up working with geographical positioning software and writing data base management programs to utilize the software. From some forty plus years of viewing the world (the first ten don't count), it is my opinion that the work place cycles between the specialist and the

generalist approach to staffing. Keep watching, whatever is the mode of the moment, it will change as the shift moves too far one way or the other and compensation takes hold to move things back the other way.

Keep up the excellent magazine!

C. HENRY DEPEW

Tallahassee, FL

You've incidentally bit on one of the main reasons for a two-party political system. Whichever party is in power for a while will eventually go too far in its preferred direction, so we need to install the other for a while to pull us back,—until they go too far!

And now, Mr. Levinson. . . .

Had any of the scientists attempted to publish their findings on Internet lists, the World Wide Web, or other suitable online services in the ingenious manner Mr. Depew suggests, the Universe would no doubt have dealt with that exigency in its now time-honored mode of dealing with troublesome computers: it would have caused a system's crash, as massive and pervasive and often as necessary. Indeed, who knows what manner of fascinating information has already been lost to the world courtesy of systems crashes in everything ranging from hard disks to mainframes and online networks in the past few decades. . . . (Puts a whole new spin on the ultimate origin of some computer viruses. And cf. Richard Dawkins's "Viruses of the Mind," in *Dennett and his Critics*, B. Dalhblom, 1993, in which he suggests that God may be a computer

meme virus. . .)

PAUL LEVINSON

Dear Stan,

This is a reply to Richard Simmers's letter in the April 1996 issue, where he erroneously berates you for your August 1995 editorial "The Anonymous Society." As I maintain the on-line account here at work, not to mention our Forum on CompuServe, I log on for an average of an hour per day, five days a week, so I think I qualify as "a serious e-mail user" as Mr. Simmers put it.

In your editorial, you *correctly* pointed out that it's very easy to 1) give a hasty, on-the-spot response to something someone else has said, 2) "flame" another who doesn't see things the way you do, and 3) say things you don't have to own up to.

Mr. Simmers seems to think that "serious" e-mail users retrieve their messages for a casual reading, and then give a well thought-out response *later*. I certainly advocate such discretion, and if more people followed this advice, there'd be a lot less misunderstandings on-line. However, people are conscious of the fact that they're paying for every moment they spend on-line, and a significant percentage respond immediately if they can.

"Flaming" others is all too easy to do—I've seen it done hundreds of times, and in weaker moments, even indulged in it myself. Once again, Mr. Simmers is correct in that "flaming" is childish and immature, but it *does* happen, especially on the Internet

where there is very little regulation.

In comparison to speaking on the phone, writing a letter, and especially face-to-face conversation, you don't have to be responsible for what you say on-line. Yes, the person you "flame" can do the same back to you, as your e-mail address appears on the message you sent . . . *but*, your "address" doesn't have to have your *name* attached. I could call myself "Avenger" if I wanted to, and no one would ever know I was Scott L. Towner. Thus, I could say just about anything I please, be as insulting and crass as I want, and the person that everyone will be angry with is "Avenger." I'm getting away Scott-free (pun intended!) If I fear a response that will be equally offensive, then I simply click on "Delete" and I never have to read it! The on-line companies like CompuServe and America On-Line would get on my case if they thought I was being too profane or abusive, yes, but they would be the only ones to know who I was. Once again, on the Internet, the only "regulation" to my comments would be if the other users got sick of me and never acknowledged my presence.

All in all, the points you made in "The Anonymous Society" are valid, and happen on a regular basis. It seems to me that Mr. Simmers was speaking more of his *own* preferences and on-line ethics than those of the general user community.

SCOTT L. TOWNER

New York, NY ■

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23-27 May

NY Space Expo/International Space Development Conference at Grand Hyatt, New York, NY. Guest include Buzz Aldrin, David Brin, G. Harry Stine. Info: Space Expos of America, Box 71, Maplewood NJ 07040. Include S.A.S.E. E-mail: 71055.2110@compuserve.com

24-27 May

WISCON 20 (Wisconsin sf conference) at Concourse Hotel, Madison, WI. Guests of Honor—Ursula K. Le Guin, plus many returning guests from 20 years of previous WisCons. Registration: \$25 until 10 March, \$35 at the door. Info: WisCon, Box 1624, Madison WI 53701-1624. (608) 233-8550. E-mail: wiscon.concom@cs.wisc.edu. Web site: <http://www.cs.wisc.edu/wiscon/>

24-27 May

DISCLAVE O96 (DC area SF confer-

nece) at Washington, D. C. Info: Disclave O96, Box 368, Gaithersburg, MD 20884. E-mail: disclave96@aol.com

29 Aug-2 Sep

L.A.CON III (54th World Science Fiction Convention) at Convention Center, Hilton, and Marriott Hotels, Anaheim, CA. Guest of Honor—James White; Media Guest of Honor—Roger Corman; Fan Guests of Honor—Takumi and Sachiko Shibano; Special Guest—Elsie Wollheim; TM—Connie Willis. Registration: \$110 until 31 December 1995, then higher. Child-in-tow (3-12 in 1996): \$35, infants: free, Supporting: \$30. This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition—the works. Join now and get to nominate and vote for the Hugo Awards and the John W. Campbell Award for Best New Writer. Info: L.A.Con III, c/o/ SCIFI, Box 8442, Van Nuys, CA 91409. E-mail: lacon3info@netcom.com

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